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(NASA-CR-51614) REACTOR IN-FLIGHT TEST SYSTEM. VOLUME 1: RIFT PROGRAM SUMMARY Final Report (Martin Co.) 117 p

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Code 5D

NASA CR 51614

MARTIN NASA-CR-61-2 (VOL. I) COPY NO. 14

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(NASA CONTRACT NAS5-648)

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REACTOR IN-FLIGHT TEST SYSTEM,

MARCH 1961

VOLUME I - PROGRAM SUMMARY (U)

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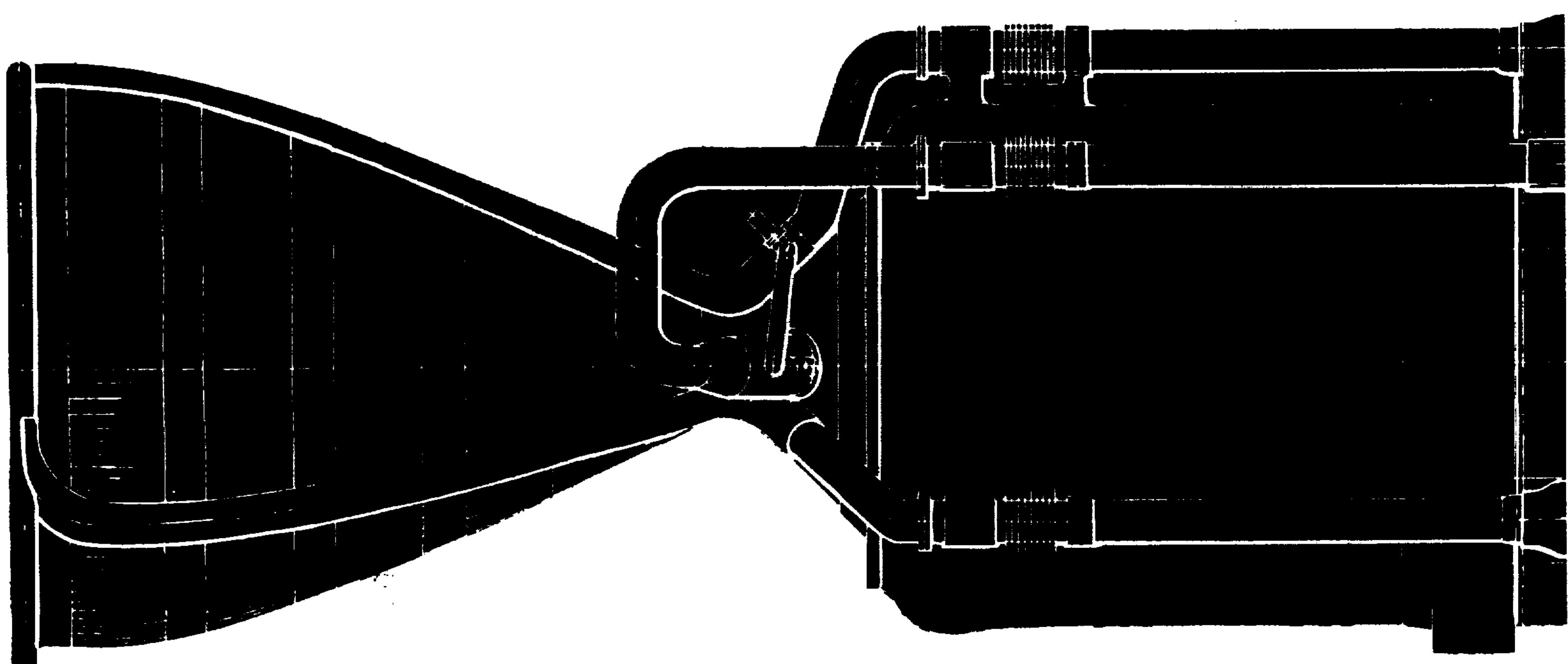

prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
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PROGRAM SUMMARY

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Approved

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FOREWORD

The final report on the Reactor In-Flight Test (RIFT) study is submitted under Article I, paragraphs B3 and B4 of Contract NAS5-648. The report comprises three volumes:

Volume I -- Program Summary

Volume II -- Airborne Vehicle Design

Volume III -- Test Program

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SUMMARY

This report on the Reactor In-Flight Test (RIFT) study establishes a flight test program plan for the first nuclear rocket. The proposed program will result in the direct development of a useful nuclear vehicle.

An R&D and an operational vehicle were studied. The nuclear stage configuration and its detail design are identical for both the R&D and operational vehicles, except that the operational propellant tank is longer. The operational nuclear stage is 260 in. in diameter with a length of 94 ft, excluding the payload package. This stage is rated at 1500 MW, using liquid hydrogen as a propellant. It has a nozzle thrust of 80,900 lb (vacuum). The operational RIFT vehicle, when used with Saturn S-I and S-II stages, provides a booster system that markedly outperforms any chemical system available during the same time period. It can boost a 47,500-lb lunar probe or a 46,500-lb escape payload.

The only major development required for the RIFT vehicle is the nuclear engine. If full program impetus is authorized at an early date, a nuclear stage can be launched in late 1965.

An inertial guidance system and self-adaptive autopilot are recommended.

A nuclear flight safety study assures a safe boost of the RIFT vehicle from Cape Canaveral. A reactor-destruct mechanism will be incorporated in the nuclear system, providing positive prevention of reactor-fragment impact on land masses. A series of initial ballistic flights followed by orbital and escape flights is recommended.

Program costs, including nuclear stage, development facilities, chemical boosters, and the nuclear engines total 521 million dollars.

I. INTRODUCTION

The purpose of the Reactor In-Flight Test (RIFT) study has been to prepare a flight test program plan that will demonstrate the operation by 1965 of a useful nuclear rocket with available boosters; to propose a nuclear engine configuration that will assure a useful payload boost capability while ensuring both radiological safety during launch and positive safe in-flight destruction of the reactor; to recommend both ground and flight test objectives; and to prepare a cost analysis that presents the total expense to the government for this program.

For several years The Martin Company has conducted investigations of the basic design characteristics of nuclear booster vehicles and their application in the space program. The high specific impulse of the nuclear rocket engine lends itself well to space application. The increase in payload that could be realized through the use of a nuclear upper stage indicated that early development of a nuclear system could extend the performance range of the large chemical boosters. Accordingly, studies were undertaken to investigate the application of a nuclear engine with current chemical boosters and to consider possible flight-testing techniques. These studies have led to the RIFT program. The principal advantages of the nuclear booster are: an increase in the ratio of payload to gross weight and an increase in the basic performance of existing large chemical boosters together with a decrease in the number of stages required for a mission.

A major goal of this study was to determine the requirements of a flight test program that would provide early demonstration of feasibility of nuclear rocket flight. Any vehicle developmental and flight test program requires an extensive examination of all aspects of the composite system. However, for RIFT, in addition to the usual environments, radiation hazards associated with the use of nuclear systems had to be considered. The international ramifications of any release of large quantities of radioactive material are such that all phases of the flight program must be safeguarded so that this contingency cannot arise. This freedom in selecting the flight test mode was restricted.

In the course of conducting the RIFT study, several methods of flight testing the first nuclear systems were considered in order to properly establish the flight test plan. The compatibility of available chemical boosters with the nuclear stage was studied, and a preliminary design of the selected flight test vehicle was made so that the complete developmental requirements, including the facilities and funding, could be evaluated.

Volume I of this report presents the objectives of the RIFT program and the determination of the flight test program. The RIFT vehicle is described, together with the test plan, facilities, schedule, and costing.

Volume II presents a complete description of the RIFT vehicle and its major systems.

Volume III includes a detailed discussion of the test plan, the facilities required for the program, and a detailed safety analysis of several typical trajectories that were considered in the course of the study.

Although the ultimate goal in the RIFT program is flight-testing of a nuclear rocket, extensive ground testing is necessary to determine those areas requiring further research or development, and instrumentation in flight. The effect of environmental conditions such as shock, vibration, and acceleration on the reactor as induced by booster and nuclear engine operation can be evaluated by ground simulation. System compatibility will be verified during captive test by simulating inputs and observing the response characteristics. Sequential operation, such as staging and restart, will be verified in the captive or ground test phases. Studies of ground and flight testing led to facility recommendations for Jackass Flats, Nevada, and Cape Canaveral, Florida, respectively.

Three flight test methods were considered: a launch from the ground; startup from an orbit, with the nuclear stage previously placed in orbit by a chemical vehicle; and upper stage operation, with the nuclear stage initially boosted to altitude, then separated from the chemical stage and flown to the desired burnout conditions. Study results show the boost-to-altitude concept is required since completely controlled trajectories can be maintained over AMR.

This method of flight testing was strongly influenced by the safety aspects of nuclear flights. A study of these aspects indicates that continued development of reactor-destruction mechanisms will provide in-flight reactor destruction, which is preferable to the next most acceptable procedure, deep-water disposition. However, before operational use of the nuclear stage, the reliability of destruct mechanisms should be proved by ballistic lob shots and suborbital controlled range flights.

Attention was directed toward selection of a launch site and range. The Air Force Missile Test Center (AFMTC) at Cape Canaveral was selected primarily because of the Saturn launch complexes and the associated extensive downrange tracking networks. An important additional consideration was the ground safety effect. The safety study indicates that at AFMTC, for a maximum credible incident on the launch pad, the resultant radiation levels will not expose personnel or the general public to excessive radiological doses.

Nuclear propulsion systems have the same design requirements and problems as chemical propulsion systems. However, certain of these problems are more complex due to the presence of nuclear radiation and were given special consideration.

In the study of the engine configuration, three basic cycles were examined. The bleed cycle was selected because of good overall performance, fewer components, availability of turbine exhaust gases for thrust vector control, and the fact that main component parts are presently under development. Two reactor power levels were used for determining the engine system performance for the bleed cycle, all estimates being made for operation in a vacuum. Thrust vector control will be provided by bleeding chamber gas to supply vernier nozzles. Examination of propellant-feed and pressurization systems led to the choice of an autogenous hydrogen pressurization system. Engine support will be provided by tubular aluminum trusswork, the portion subject to radiation heating being incorporated into the engine propellant-feed system and thus cooled by liquid hydrogen.

Comprehensive performance studies, aided by extensive computer utilization, provided explicit data that are presented in tables and curves and show the basis for final nuclear vehicle configuration. Extensive consideration was given to structural dynamics, aerodynamics, and staging, because of the unique configuration dictated by the location of the nuclear engine with respect to the booster stages.

The inertial guidance system meets the guidance requirements for RIFT. A self-adaptive autopilot, instead of a linear system, will provide flight control because of its flexibility and ability to perform information processing. All electrical power will be provided by a 28v primary supply from a silver-zinc battery. A study of in-flight instrumentation requirements resulted in the selection of a two-level pulse code modulated, frequency-modulated system capable of 392 analog channels and 12 of digital bi-level data.

Examination of the radiation environment was necessarily extensive and provided data for design of protective shielding and a recommendation for materials and component qualification.

The facility considerations were quite detailed and included manufacturing capabilities such as tooling; engineering support facilities exemplified by the component laboratories, vertical test fixtures, and propulsion laboratory; and captive test and launch.

The test plan includes a complete program schedule and cost.

II. PROGRAM OBJECTIVES

The fundamental objective of the RIFT study is to determine a complete program plan for flight testing the first nuclear rocket engine. The flight testing of this engine must be conducted safely and in such a manner as to yield maximum information applicable to operational usage of nuclear vehicles. To develop the nuclear vehicle for use in the national space program, it is desirable to conduct the flight testing as soon as a flight-certified engine can be made available. It is the consensus of several engine manufacturers that such an engine can be developed by 1965. On the basis of these opinions, the study considered the feasibility of developing a satisfactory vehicle to perform flight testing at that time.

A. PURPOSE OF FLIGHT TESTING

The primary objective of the flight testing program is to demonstrate the adequacy of the reactor-destruction system in flight. Safety studies have shown that a developed reactor destruction system is required before full operational flight can be achieved. This system will have to be developed concurrently with the engine so that the proper interrelation can be established. The operation of this system must be adequately demonstrated in the first flight tests before mission accomplishment flights can be performed.

A second major objective in the RIFT program is the demonstration of satisfactory nuclear rocket operation when subjected to full flight environment.

The operation of the remainder of the systems can be determined in ground testing since they will consist of flight-qualified items that will be in use in the 1965 time period. System compatibility can be verified during captive test by simulating trajectory inputs and observing the response characteristics. The guidance and autopilot system can receive programed inputs corresponding to normal and abnormal conditions, and the effects on their operation will be established. Final verification of the complete vehicle operation, however, must be obtained in flight.

Sequential operations, such as staging and restart, can be verified in the captive or ground test phases, since these operations will be based on techniques that will be in use during the flight test period.

The first few flights of the RIFT vehicle, therefore, will demonstrate and verify the safety system, as well as system operation and compatibility. The remainder of the RIFT program will consist of flights that lead to the development of a desired operational nuclear vehicle.

For this reason, the RIFT study established a program that was directed toward an operational space booster, thus giving a concrete goal to the development effort required for the flight test system.

B. VEHICLE DESIGN

Several available chemical boosters were studied for application in the RIFT program. These systems were studied to determine the most effective method of conducting the flight testing. In arriving at the selected system, the objective of producing an operational vehicle from the RIFT program was of major significance.

A preliminary design of the RIFT vehicle was established, and the composite developmental plan was based on this configuration. Since the objective of the RIFT vehicle is flight testing of the first nuclear engine, considerable emphasis was placed on the propulsion system and its effect on vehicle design. The nuclear rocket engine presents a new environment to the vehicle, and this markedly influences the manner in which the total system is evolved. Consideration must be given to location and cooling of major structural components in the engine compartment, the manner in which control forces are obtained, the propellant-feed system effects, and the effects of nuclear radiation on the electro-mechanical equipment. These are all new considerations in the field of rocket design and, in some cases, basic approaches must be modified for their inclusion.

The vehicle design objective was to give serious consideration to simplifying systems in the engine compartment to reduce the design and development problem for the new propulsion device. At times this resulted in small penalties in specific impulse and performance, but this was accepted if a major component development could be eliminated. Wherever possible, however, the objective of developing an operational vehicle from the RIFT program dictated that performance be a dominant factor.

To maximize the reliability of the vehicle, the design was based on the use of major equipment either presently in use or under development for use in the near future. In this way, the problems become primarily those of adapting equipment to the vehicle rather than developing new items.

C. TESTING AND FACILITIES

The complete planning, scheduling, and costing for the RIFT program were based on development of the selected RIFT vehicle. The testing approach was taken from manufacturing and component development through system development and checkout to the ground and flight testing phases. Because of the complexity and cost of the program, emphasis was given to progressive testing. Each step in the test program was preceded by extensive testing of the cumulative equipment assembled for the test in question.

RIFT facility requirements were established and preliminary designs for major new facilities were completed to accurately estimate cost. The manufacturing and engineering facilities required at the contractor's site were considered, as well as the captive stands at Jackass Flats, Nevada, and the stand modifications at the launch site.

The manufacturing and engineering facilities are direct extensions of comparable facilities for large booster systems such as the Titan. The engineering test cells for static and dynamic testing of the vehicle structure and systems are similar in design but larger than the type used in the Titan program.

[redacted]

Emphasis was given to design of the test complex required at Jackass Flats for vehicle development and captive testing. It is at this point that the vehicle and engine mate for hot firing, and the requirements for remote operation and handling had to be considered in the design of a large-vehicle captive stand. At this facility, the complete nuclear stage undergoes full operation, and the performance of all systems must be observed and monitored to determine their behavior.

The test program at Jackass Flats requires extremely close liaison between the vehicle and engine contractors to ensure that all testing is satisfactorily conducted. The nuclear engine is coupled much more closely to the vehicle operation than in the case of chemical systems. The radiation heating of the propellant affects the pump-inlet conditions, and the proper evaluation of this effect is important in development of a nuclear stage. Since both the vehicle and the engine are in developmental phases and are so closely coupled, the captive test stand crews should include some personnel from the engine stands. The crews for the flight launchings should also receive training at the vehicle facility to become proficient in handling the nuclear stage.

The launch site facilities were reviewed for compatibility with the RIFT vehicle. The only major addition to the Saturn launch complex, required by the RIFT vehicle itself, is a special engine-handling area where the reactor is assembled in the engine and checked out before flight. The checkout includes a very low-power critical experiment to ensure proper assembly. This critical experiment requires a separate facility and an associated exclusion area as a safety precaution.

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D. SCHEDULE AND COSTS

The schedule and costs for RIFT vehicle development were the final objectives of this study. The schedule was based on the required developmental steps and included the effects of major facility construction and long-lead items. The schedule was keyed to the engine-development program and chemical booster availability. It was determined that the program is controlled by engine development. The vehicle can be made ready for flight in late 1965 if captive testing can be initiated on schedule. The experience of The Martin Company indicates that the time span allowed for vehicle development is adequate.

The cost analysis corresponding to the development schedule was based on estimates for all phases of the program and includes the facility requirements developed in this study.

[redacted]

III. FLIGHT TEST MODE

Several methods were proposed for conducting the first flight tests of a nuclear rocket stage. These methods are:

1) Launch direct from the ground;

2) Startup from an orbit, in which the nuclear stage has been placed there by a chemical vehicle;

3) An upper-stage operation, in which the nuclear stage has been initially boosted to altitude, is separated from the chemical stage, and flown to the desired burnout conditions.

To select the method for initial flight testing, it is necessary to establish the reasons for conducting the flight test and the type of information that is desired from the test, with full consideration being given to safety of operation.

In light of the extremely large financial investment that will be required in this program, it would be most desirable if the flight testing could produce a vehicle that would have direct application in the space program. The final phases of the RIFT program should, if at all possible, represent the developmental phases of an optimum operational space vehicle. In this way the RIFT program will not only determine the characteristics of a nuclear rocket in flight and demonstrate the behavior of a nuclear rocket in different modes of operation, but will also represent, in part, the required R&D phases of an operational booster program. If the RIFT program did not follow this path, but rather, selected a flight test technique that would appear to be more economical or available at the earliest date, it could well be that the development of the operational vehicle would require a separate program resulting in a total expenditure of time and money considerably in excess of a unified RIFT program.

Preliminary investigations of the use of nuclear vehicles using the RIFT engine have shown that a useful operational stage can result from the RIFT program. This application is a third stage with Saturn S-I and S-II stages. This stage can deliver payloads on the order of 48,000 lb to velocities sufficient for transfer to the vicinity of Mars or Venus. In comparison, the Saturn S-I, S-II, S-IV all-chemical booster delivers a payload

[redacted]

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of 16,400 lb to comparable velocity. If the nuclear stage were placed in orbit chemically, and then used to develop the escape velocity, the payload would be about 19,000 lb. This does not provide the magnitude of performance increase that the upper stage does, and is not considered attractive at this time.

The conclusions presented above indicate that the RIFT program should be aimed at the development of a third-stage booster for Saturn. Emphasis should be placed on all testing being conducted with the RIFT stage operating as an upper stage.

The major item to hold constant throughout the RIFT program should be the basic engine compartment. If this were done, the engine development program would proceed directly to the qualification of the powerplant for its operational mode, and redesign and corresponding qualification time and expense can be eliminated. Consistent with the need to develop the operational engine compartment is the desire to develop the basic vehicle configuration. The size of the nuclear stage should be consistent with the Saturn vehicle. Analysis of the three-stage configuration has shown that a 260-in. diameter nuclear stage containing the optimum propellant loading of 90,000 lb of liquid hydrogen is dynamically compatible with the S-I and S-II stages, providing an adaptive autopilot is used. Thus, the desired nuclear stage for RIFT should be the 260-in. system using an engine designed for use as a third stage with Saturn S-I and S-II stages.

The selection of the method of flight testing is strongly influenced by the safety aspects of nuclear flights. The investigation of nuclear safety is reported in Volume III. The general conclusions, when restated in terms of the three possible modes of flight testing are:

1) The radiological hazards associated with launching a nuclear stage, whether as an upper stage or directly from the ground, are controlled by the excursion possibility. The result of an excursion is considered safe on the basis of the radiological standards established by the AEC, providing isolation areas are available;

2) An unacceptable hazard exists if the reactor were to fall into shallow coastal waters used by the general public. This hazard is applicable to all modes of test flight if the flight trajectory passes over such waters. The extension of current vehicle destruction systems can lead to virtual elimination of this hazard;

[redacted]

3) Controlled or predictable disposition of the engine in deep ocean waters is probably acceptable. The destruction mechanism required for shallow-water impact, however, can be used to remove excursion hazards, if necessary;

4) Random re-entry of the nuclear engine with probable land impact is unacceptable and must be eliminated. This hazard applies both to the upper stage use where the vehicle is being injected into orbit, or is passing through orbital velocity to attain escape velocities, and to the nuclear stage restart from a parking orbit. The probability of random re-entry is greatest for orbit injection. The relative position of orbital startup and the escape flight depends on the reliability of the nuclear engine, and, therefore, cannot be ascertained at this time. The basic event must be considered possible in all cases. A satisfactory solution is required to permit nuclear flight in the random re-entry domain.

On the basis of these considerations, the first flights of a nuclear rocket vehicle must be restricted to ballistic lob shots where the impact of the engine is predictable throughout flight. This lob shot can be conducted either as a ground launch or as an upper stage, depending on the aims of the total program.

A. GROUND LAUNCH

The basic characteristics of a ground-launched vehicle as opposed to an upper stage lie in the area of flight controls and engine configuration. The vehicle at launch and aloft will be subjected to winds that can introduce trajectory deviations and vehicle instabilities unless corrected by the flight control system. Since these aerodynamic forces are large and variable, provisions must be made to produce large, fast-acting control forces to compensate for the disturbances. The nuclear engine under study by NASA/AEC at this time does not include provisions for such control-force requirements. They can be provided by several means:

1) Driving a special set of vector control nozzles by an auxiliary gas generator;

2) Using main thrust as the corrective system by engine gimbaling;

3) Markedly increasing the chamber bleed for the bleed cycle engine and flowing the additional gas through vernier nozzles for the required force.

Ground launch will require that all vernier nozzles and the main engine nozzle be sized to prevent flow separation from occurring during flight at low altitude.

The development program for an engine to operate under these conditions can be introduced at this time, and such an engine could be available for the flight test program on the desired schedule. The most direct solution to the flight control problem would be the separate gas generator. Effective systems of this type are now available. The major problem would be qualification of the system in the radiation environment.

Engine gimbaling is questionable because of the high response rate required, coupled with the extremely heavy mass of the nuclear rocket motor.

The vehicle design for the ground launch presents no major problems. The structural design for an optimum upper stage application discussed previously can meet the design loads for ground launch without any major modifications. The adaptive autopilot lends itself to application for either stage. The major consideration in this type of test flight is the requirement for a separate engine development program.

The data obtained from a ground launch are only partially applicable to the eventual use of the nuclear engine. A ground launch will provide information on steady-state operation, controlled shutdown in flight, and final vernier phase operation, as well as provide a means for demonstration of the required re-entry safety system. It will not supply any information on the in-flight staging operation that is of major concern in the operational mode.

B. ALTITUDE START

The upper stage method of testing the nuclear engine is very attractive when viewed in the light of the eventual use. The engine program now proceeds directly toward the operational item. By staging at high altitudes, the control requirements become those of the Saturn third stage since, at this point, no major external forces are acting on the vehicle. This consideration removes a major disadvantage of the ground launch concept while not introducing any foreseeable delays into the engine and vehicle program.

The use of an altitude start can provide the majority of the in-flight data that will be required to establish design verification. The staging sequence will be demonstrated; the ability of the engine to operate satisfactorily after undergoing the boost environment, particularly the shock, vibration, and acceleration conditions, will be established; steady-state operation of the entire system will be demonstrated; thrust shutdown and solo vernier operation will be demonstrated; and the re-entry safety system operation will be verified.

A major advantage of either ground- or altitude-start ballistic shots is the relatively short burning time of the engine. The ballistic shot can be made with burning times on the order of 200 to 300 sec. This can result in flight with engine qualification required only for 300 sec; the mission flights are introduced later giving additional time for final engine flight certification.

The primary advantage of the altitude start is the ability to demonstrate the range of operation that will be required in the desired use of the engine, which was presented earlier, namely, the third-stage application.

Following the successful altitude-start ballistic lob shot, the nuclear stage can be used to perform some limited space missions, e.g., injection of payloads into orbits ranging upward from 300 n mi. Depending on the mission selection, restart can be demonstrated in these flights, if desired.

C. ORBITAL START

The controlling factor on the use of orbital start for initial flight testing is the random re-entry hazard that is present. Until a positive safety system has been demonstrated, orbital startup gives rise to a credible incident that is unacceptable. After the safety system has been proved, orbital start can be used as a flight demonstration method. However, such flights are not attractive for this engine when considering the payload performance that can be achieved from orbit flights.

The Saturn S-I and S-II stages will provide the only currently planned booster that can place a sufficient initial weight in orbit to warrant nuclear flight. Therefore, at the time that orbital start can be performed, the mating of the nuclear stage as a third-stage booster can also be accomplished. Considering the marked advantages that result from moving directly into the operational mode, the orbital start does not offer any great attractions at this time.

D. CONCLUSIONS

Preliminary analysis indicates conclusively that the nuclear engine being developed for the RIFT program exhibits a high performance advance when used as a third stage with Saturn S-I and S-II stages. Performance is markedly better than the chemical Saturn and provides a major increase in deep-space payloads. The use of the nuclear engine as a propulsion system for use from a parking orbit results in performance that is comparable to chemical propulsion applications. This is primarily caused by weight in orbit limitations during the 1965 to 1970 time period. On the basis of these results, the third-stage application should be the goal of the RIFT program, and all testing aimed at this result.

The safety aspects of flight as shown in Figure III-1 require that a re-entry safety system be developed before use of the nuclear engine at orbital conditions.

[redacted]

Problem Area	Prelaunch	Launch Pad Early Ascent Abort	Later Chemical Stage Abort	Ballistic Mission Preorbital Abort	Re-entry from Orbit Successful and Unsuccessful Missions	
Problem	Accidental Criticality with Excursion		Shallow Water Impact	Deep Water Impact	Random Re-entry	
Consequences	1. Direct Radiation 2. Fission Product Release a. Cloud Formation b. Launch Pad Contamination		Excursion with Contamination of Water, Beaches, and Marine Life	Excursion with Fission Product Release	Water Impact Excursion a. Release b. Contamination	Land Impact 1. Mechanical 2. Direct Radiation 3. Contamination
Mission Affected Ballistic Orbital Escape						
Problem Remedy	Prevention	Fragmentation			1. Vaporization 2. Controlled Re-entry and Recovery	
Countermeasures	Boron Steel Wire in Coolane Channels	Destruct Device Acting on Core			Vaporization 1. By Explosives a. Conventional b. Nuclear 2. Self-Destruction (Semipassive) a. Operation without Coolant b. Use of Oxygen c. Water Injection d. Chemical Additives	

Fig. III-1 Summary of Safety Problems and Countermeasures

[redacted]

[redacted]

It is concluded that the RIFT program should begin with a series of altitude-start ballistic lob shots. These flights will provide the primary design verification data necessary to proceed into space mission flight. A major objective of the lob shots is to demonstrate a re-entry safety system.

Two basic systems are recommended for the re-entry safety. system. The first is a chemical, or active system, in which the reactor is effectively destroyed in flight by a chemical reaction (introducing oxygen into the reactor and burning it up). The second type is the aerodynamic, or passive, system, in which the reactor is completely destroyed by aerodynamic heating during the course of re-entry.

Both types of safety systems should undergo extensive research and development during the RIFT program. The flight test program is established around the demonstration of both types of systems.

To demonstrate chemical destruction, where vehicle velocity is not of extreme importance, the test can be conducted on a controlled range with vehicle burnout velocities on the order of 15,000 ft/sec.

Demonstration of the passive destruction method requires vehicle velocities on the order of 22,000 ft/sec to simulate re-entry conditions from circular speeds.

An extension of the high velocity shots could be an orbit-injection flight with demonstration of mission fulfillment.

Following these shots, the nuclear stage should be used on a series of mission demonstration flights as a third stage with Saturn S-I and S-II as soon as all stages are available.

To minimize redesign and qualification efforts, the RIFT nuclear stage, in particular the engine compartment, should be designed initially for application with the S-I, S-II stages.

<u>Launch site and range selection</u> - The most desirable launch site for the RIFT program is an area that in the 1965 to 1967 time period will have all of the major launch and range facilities available. This requires no heavy facility construction with its attendant fiscal problems. The two major launch areas now in use -- AMR and PMR -- are in this category.

[redacted]

AMR received the most serious attention since the major Saturn launch complexes are under construction, and extensive downrange tracking networks are available. The major item to be resolved in selecting a launch site is the ground safety effects.

The analysis of nuclear incidents associated with the launch operation is discussed in detail in Volume III of this report. The results of this study indicate that, for a maximum credible incident on the launch pad, the resultant radiation levels will not expose personnel or the general public to excessive radiological doses. The major radiation hazards will be restricted to the area of the launch site. All personnel within a mile of the launch site, except those within the blockhouse or comparable safe areas, should be evacuated as a safety precaution. If an incident were to occur, the clean-up operations could begin within 2 days and the normal activities of the base resumed within an additional 2 days. Maximum radiation doses that would be received by the general public are 27 mrem of gamma and 61 mrem of beta radiation. This total of approximately 90 mrem is 10% of the permissible emergency single exposure limit. This maximum dose would occur at a distance of 2 mi from the incident.

Since radiation levels are within accepted tolerances and the total shutdown time does not appear to be excessive, AMR is recommended for the launch operations of the RIFT program.

The AMR downrange tracking net permits full RIFT flight testing without any major new installation or extensive modification.

IV. AIRBORNE CONFIGURATION

Two distinct airborne vehicles have been analyzed; an R&D vehicle and an operational vehicle. The two-stage R&D vehicle consists of a Saturn S-I, and the R&D nuclear stage. The operational vehicle consists of Saturn S-I, S-II and the operational nuclear stage. The nuclear stage configuration and its detailed design are identical for both the R&D and operational vehicles, except that the operational propellant tank is longer. The nuclear stage is an all-aluminum structure 260 in. in diameter consisting of a liquid hydrogen propellant tank with ellipsoidal domes, forward and aft tank skirts, and a nongimbaled nuclear engine. Comparative sketches are shown in Figure IV-1.

The two-stage R&D vehicle is 170 ft long, capable of boosting a 32,795-lb payload into a 100 n mi orbit. The R&D nuclear stage is 77 ft long, contains 65,000 lb of usable propellant, and has an engine thrust of 54,500 lb.

The three-stage operational vehicle is 249 ft long, and is capable of boosting a 42,640-lb payload to escape velocity. The operational nuclear stage is 94 ft long, contains 90,000 lb of usable propellant, and has an engine thrust of 80,900 lb.

The system characteristics of a nuclear propulsion system differ from those of conventional liquid propellant systems in features such as propellant and material heating through radiation, thrust vector control, engine configuration, and thrust buildup and decay. The engine design criteria include the capabilities for 1000 MW at 4090°R gas temperature, and nozzle thrust of 54,500 lb with a growth potential to 1500 MW at 4460°R, and nozzle thrust of 80,900 lb.

Liquid hydrogen manifolded through the tubular members of the lower third of the engine truss prevents excessive structural temperatures due to nuclear heating.

Vernier nozzles mounted on the engine truss provide pitch, yaw, and roll control by using hot gases from the pump turbine exhaust.

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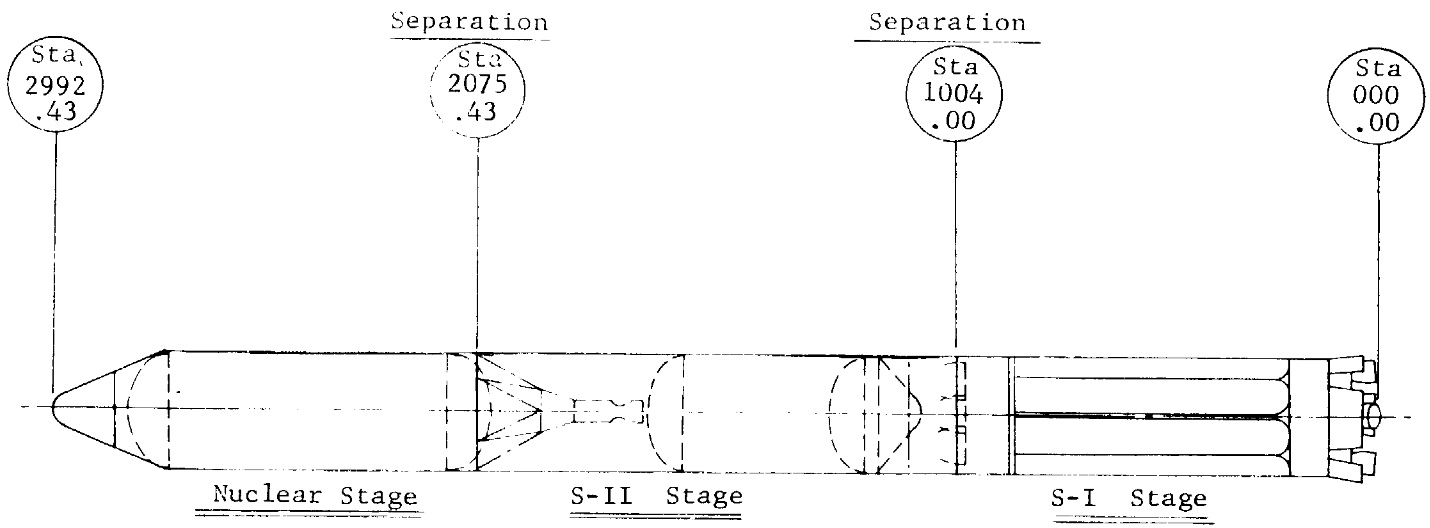

Saturn S-I, S-II/Nuclear

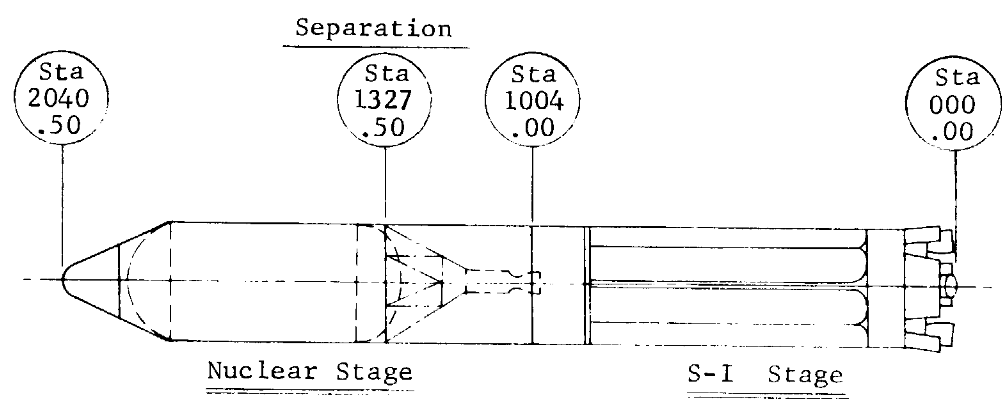

Fig. IV-1 RIFT Configurations

[redacted]

The nuclear stage is separated by separation rockets mounted on the nuclear step. The separation rockets provide a total impulse of 64,000-lb-sec. A continuous explosive charge is used to shear the structure at the stage interface.

An inertial guidance system is used. This system is self-contained, meets the requirement for mission flexibility, and is not restricted by the limits of line of sight, look angle and elevation angle.

A self-adaptive autopilot flight control system stabilizes and directs the booster flight and subsequent stages from launch to engine burnout.

All electrical power requirements are furnished by a 28v automatically activated silver-zinc battery.

A pulse code frequency modulated telemetry system operating in the 2200 MC band, is used for airborne instrumentation measurements from the nuclear and booster stages.

A. PROPULSION SYSTEM

Basically, nuclear propulsion systems possess the same design requirements and problems as chemical propulsion systems; however, certain of these problems are more complex due to the presence of nuclear radiation.

The effects of radiation result in such major problems as propellant and structural heating, engine and tank configuration, thrust buildup and decay, and safety from nuclear reactor hazards.

The study and design of the propulsion system for the nuclear stage were based on the following design criteria:

1) A hydrogen-cooled reactor rated at 1000 MW developing 4090°R gas temperature with a growth potential to 1500 MW and a gas temperature of 4460°R;

2) A regeneratively cooled nozzle capable of ready removal from the reactor pressure shell;

3) Turbopump assembly integral with a geared inducer capable of operating at NPSH of 1 psi;

4) Operational engine to demonstrate 90% true reliability at a confidence level of 90%;

5) Engine capability of altitude start with restart under zero gravity;

6) Nongimbaled thrust chamber and all forms of thrust misalignment shall be limited to ±1/8 in. and ±0.5 deg.

1. Engine Configuration

In the study of the engine system, three basic cycles were examined: gas generator-turbine drive, bleed cycle, and topping cycle.

Within the gas generator-turbine drive cycle, an LH_2-lox gas generator drives the turbopump assembly, which feeds LH_2 to the regeneratively cooled nuclear thrust chamber. During engine operation the turbine exhaust gas is used in vernier nozzles for pitch, yaw, and roll control. After engine shutdown the control nozzles are operated on gas from the gas generator, which is being bypassed around the turbine.

The bleed cycle uses cooled thrust chamber gas for the turbine-pump drive. Several configurations based on this cycle were studied in which various means of obtaining thrust vector control were incorporated as a part of the engine.

The main characteristic of the topping cycle is the use of propellant vapor that has been generated during the regenerative cooling process of the nuclear thrust chamber to drive the turbine-pump assembly. After it has left the assembly the vapor is returned to the thrust chamber. Various arrangements for thrust vector control were also studied, based on this cycle.

All of the engine configurations studied were based on reactor data from NASA and the use of the Rocketdyne Mark IX turbopump assembly.

After critical evaluation of the various arrangements, the engine bleed cycle was selected for the following reasons:

1) Overall performance was not markedly lower than the highest performance of the other configurations;

2) Fewer components are used, resulting in a lighter system weight and greater engine system simplicity;

3) Flexibility in the use of turbine exhaust gases for thrust vector control is possible without complexity;

4) The main component parts for this type of cycle (nozzle and turbopump) are now under development.

A schematic of the engine is shown in Figure IV-2. In this system liquid hydrogen is delivered from the pump discharge to the cooling manifold of the main nozzle through a flow system that uses part of the structure to cool that portion of the engine truss that is subject to the highest radiation heating. A small portion of the cold propellant is diverted to a bleed gas collection manifold where it is mixed with chamber gas to provide an acceptable temperature (1800°R) for turbine drive. Turbine speed and the turbine bypass flow are governed by the turbine bypass valve.

2. Engine Performance

Two reactor power levels were used for determining the engine system performance for the bleed cycle. Considering only sufficient chamber bleed to drive the turbine, the performance values determined are shown in Table IV-1.

Since the RIFT propulsion system is to be used in an upper stage, all performance estimates were made for operation in a vacuum. Although large area ratios are favored for the main nozzle, increasing the vernier nozzle area ratio above 30:1 will not produce a realistic gain in performance.

3. Thrust Vector Control

The choice of thrust vector control systems has a bearing on the selection of the engine cycle, the overall engine system performance, and engine configuration. Although the in-flight vector control requirement is nominally less than 1% of the main engine thrust, additional attention must be given to the problem of main chamber thrust misalignment.

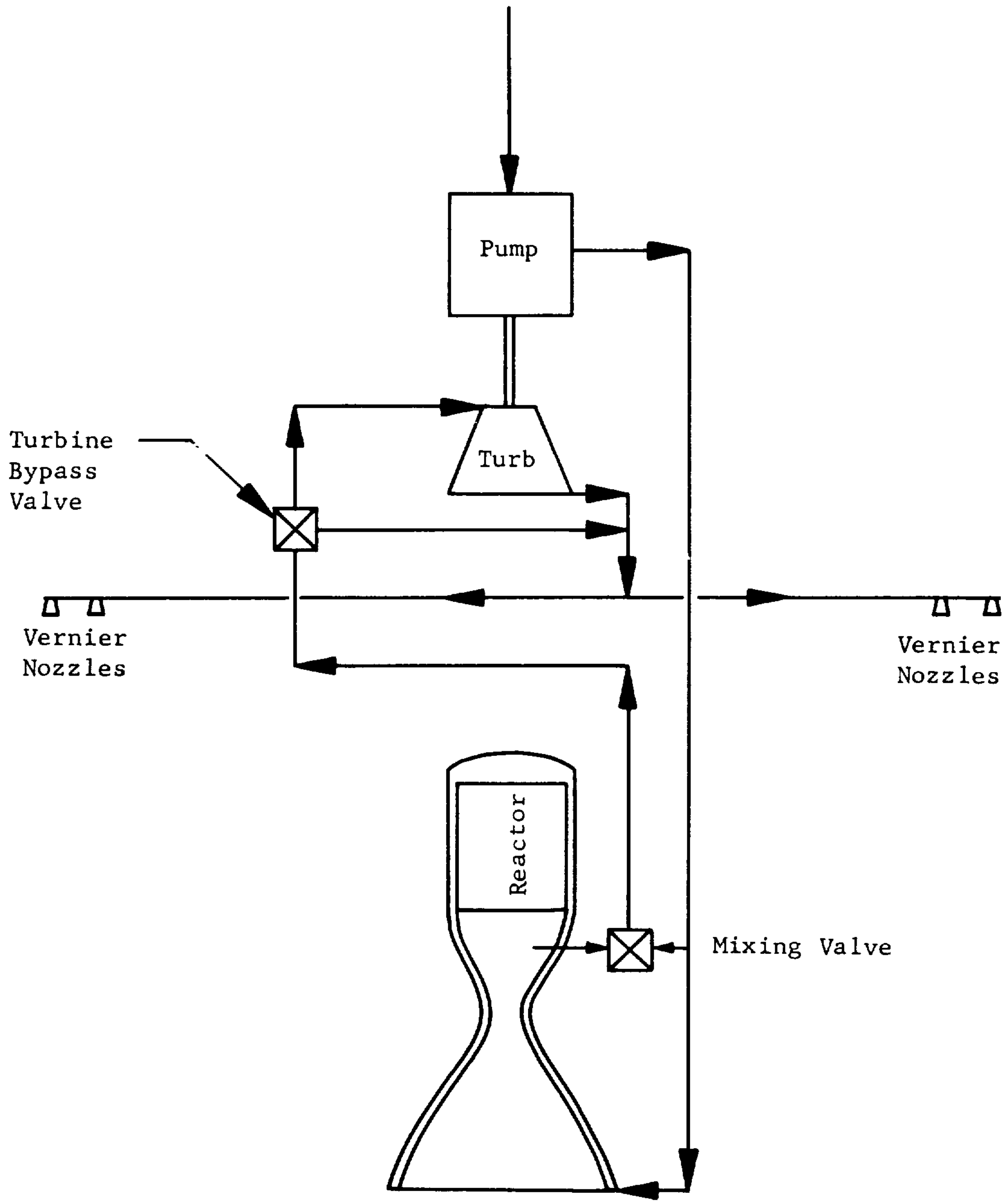

Fig. IV-2 Engine Schematic

Table IV-1. Performance Values

Reactor Power (MW)	1,000	1,500
Chamber		
Gas Temperature (°R)	4,090	4,460
Pump Flow Rate (lb/sec)	70	100
Thrust (lb)	54,500	80,900
Specific Impulse (sec)	801	842
Chamber Pressure (lb/in.^{2})	550	750
Area Ratio	40	40
Vernier		
Thrust (lb)	767	1,500
Specific Impulse (sec)	374	374
Chamber Pressure (lb/in.^{2})	59	82.3
Area Ratio	20	20
Engine (neglecting vernier thrust)		
Thrust (lb)	54,500	80,900
Specific Impulse (sec)	779	809

Misalignment may exist as mechanical misalignment due to structural inaccuracies, and/or gas dynamic misalignment caused by nonuniform gas flow pattern in the thrust chamber. It is estimated that total misalignment causes the required vernier control system performance to be increased twofold or more over that needed for attitude control if no misalignment existed.

For the two-stage Saturn C-2 booster vehicle, the total in-flight control requirements for the 1500 MW nuclear engine can be satisfied by bleeding an additional amount of chamber gas for use in the thrust vector control system. The loss encountered is less than 2% in engine system specific impulse. The Saturn S-I booster with the 1000 MW reactor requires a control thrust of 2600 lb and the additional chamber gas bleed.

An alternate method for obtaining main chamber thrust vector control by gimbaling the nozzle has been investigated. This method, however, was discarded because of the development problems involved. Moreover, reduced engine reliability will result with structures and mechanism exposed to a high radiation field.

For vehicle attitude control after nuclear engine shutdown, the ducting of turbine exhaust gas to the vernier nozzle system is not possible. During this period of flight, the large propellant tank, filled with residual pressurizing gas, is capable of supplying energy to a separate vernier nozzle system for periods in excess of 30 sec.

4. Propellant-Feed and Pressurization System

A comprehensive study has shown that three forms of propellant heating -- aerodynamic heating, bulk heating, and recirculation heating -- must be accounted for in the design of a nuclear stage.

a. Aerodynamic Heating

Aerodynamic heating results from the free convective transfer of heat from the missile boundary layer through the tank skin to the hydrogen propellant. Analyses have been completed that indicate the propellant temperature will rise 1°F due to aerodynamic heating while boosting through the atmosphere. This value is valid for flights using the Titan II booster, the Saturn S-I booster, and the two-stage C-2 Saturn booster, and is based on use of 0.125-in. corkboard bonded to the outer surface of the nuclear stage propellant tank.

b. Bulk Heating

Bulk heating is the maximum change in temperature caused by the gamma energy deposition resulting from the final unit volume of liquid hydrogen flow, influenced by various tank-bottom geometries. There are two sources of gamma radiation that contribute to the bulk heating phenomenon. The first is the primary gamma radiation from the reactor, and the second is gamma radiation resulting from neutron capture in the tank bottom. In addition to calculating the temperature rise due to radiation bulk heating, the reactor shielding requirements that will maintain a propellant temperature change equal to or below any preselected value must be determined. However, the results obtained from the bulk heating study do not represent an optimization for the entire problem of propellant heating, but rather, form a part of the total shield and reactor-tank separation distance optimization.

c. Recirculation Heating

Recirculation heating results from the localized energy deposition by escaping neutrons from an unshielded reactor in a relatively thin layer of hydrogen adjacent to the tank bottom. This heating results in a phenomenon similar to that of free convective heat transfer in the vehicle tank, and the formation of stratified layers of hydrogen. The gross effects of this convection, in the extreme case, will be an exponential propellant temperature rise near the end of nuclear stage powered flight to a magnitude that cannot logically be compensated for by tank pressure without a large increase in tank weight. An analytical model of the internal flow in a propellant tank with various tank-bottom geometries has been developed, and an analysis of this heating phenomenon was conducted using various incident neutron flux levels. Test results from a simulation test device at the Martin hydrogen facility have confirmed the basic assumptions of this analytical model. For realistic configurations of a nuclear stage, shielding will be required, with the optimized stage requiring approximately 95% shielding of the neutron flux. The conclusions from the study of convective recirculation and its effect on stage weight have been included in the overall stage optimization study. The results are a 12.3-ft reactor tank separation distance and 1760 lb shielding weight.

d. Pressurization Systems

Stored gas and autogenous pressurization systems, the influence of trapped gas on tank weights, and transient requirements and their related effects were investigated to obtain an efficient method of pressurization for the RIFT propulsion system. The autogenous pressurization system lends itself readily to the nuclear engine and was selected for the nuclear booster for the following reasons:

1) An autogenous hydrogen pressurization system is the most desirable from a weight and reliability consideration;

2) Trapped cold gas weights are closely offset by the reduction in tank weight due to higher tank material strength at lower wall temperatures;

3) The transient NPSH requirements are much less severe than those in existing cryogenic missiles and are easily met with the proposed system. This is due chiefly to the longer startup times expected for the nuclear engine in comparison to chemical engines. Low flow rates, less than 1.0 lb/sec of hydrogen gas, can be extracted from the dome of the thrust chamber to provide a source of hydrogen for the propellant tank autogenous pressurization system. The lowest flow rate would be obtained at the optimum gas temperature of 300°R. This form of hydrogen gas bleed can also be combined with the bleed requirements anticipated for the control-rod drive mechanisms.

B. PERFORMANCE

On the basis of performance, the nuclear stage was sized as an optimum third stage for the Saturn S-I/S-II configuration when used for an escape mission. The propellant optimization study resulted in off-loading the first stage of the Saturn vehicle and sizing the nuclear stage for 90,000 lb of propellant. The second stage of the Saturn vehicle will be filled to capacity.

The resulting size of the nuclear stage was far from optimum for low-altitude orbital missions when used with the Saturn S-I stage alone and with the engine down-rated. Since the early flight date depends on using this configuration, the nuclear stage for these flights was shortened to a size near optimum for the 100-300 n mi eccentric orbit. This mission was selected as being typical of low-altitude orbital missions.

1. Basic Data and Methods

Basic mission-payload performance data were computed assuming a point mass moving about a spherical, rotating earth. Aerodynamic drag was included and the 1956 ARDC standard atmosphere was used. The final configuration of each vehicle was simulated by a six-degree-of-freedom trajectory model confirming performance data and demonstrating that the respective missions can be accomplished without exceeding vehicle constraints. Aerodynamic data and wind profiles are presented in other sections of this report.

2. Performance and Configuration Data

The performance and configuration data for the Saturn S-I, S-II/Nuclear are presented in the accompanying tabulation.

	S-I	S-II	Nuclear
Propellant	Lox/RP-1	Lox/LH_2	LH_2
Thrust (lb)	1,504,000 (sea level)	800,000 (vacuum)	80,900 (vacuum)
Specific Impulse (sec)	257 (sea level)	420 (vacuum)	809 (vacuum)
Usable Propellant (lb)	587,540	324,920	90,000
Flow Rate (lb/sec)	5851.95	1904.8	100
Thrust Gradient (lb/psi)	13,157.21	0	0
Duration of Phase (sec)	100.4	170.58	900
Jettisoned Weight (lb)	101,000	36,540	20,560
Diameter (ft)	21.67	21.67	21.67
Payload (lb)			42,640
Velocity Gain (ft/sec)	3,421	11,110	21,649
Escape Mission, Burnout Velocity (ft/sec)			36,180

Performance data for the Saturn S-I/Nuclear are presented in the accompanying tabulation.

	S-I	Nuclear
Propellant type	Lox/RP-1	LH_2
Thrust (lb)	1,504,000 (sea level)	54,500 (vacuum)
Specific Impulse (sec)	257 (sea level)	779 (vacuum)
Usable Propellant (lb)	684,620	65,000
Flow Rate (lb/sec)	5851.95	70
Thrust Gradient (lb/psi)	13,157.21	0
Duration of Phase (sec)	116.99	928.57
Jettisoned Weight (lb)	103,800	18,805
Diameter (ft)	21.67	21.67
Payload (lb)		32,795
Velocity Gain (ft/sec)	10,165	15,767
100-300 n mi Eccentric Orbit Burnout Velocity (ft/sec)		25,932

3. Nominal Performance

The performance capability of the Saturn S-I, S-II/Nuclear for direct injection into circular orbits, eccentric orbits, and coasting injection into a circular orbit is shown in Figure IV-3. The coasting injection into circular orbits uses the restart capability of the nuclear stage.

Shaping the trajectories for extra-terrestrial missions produces the following payload capabilities.

Mission	Payload (lb)
Lunar Probe	47,500
Escape	46,500
Venus Probe	44,000
Mars Probe	43,000

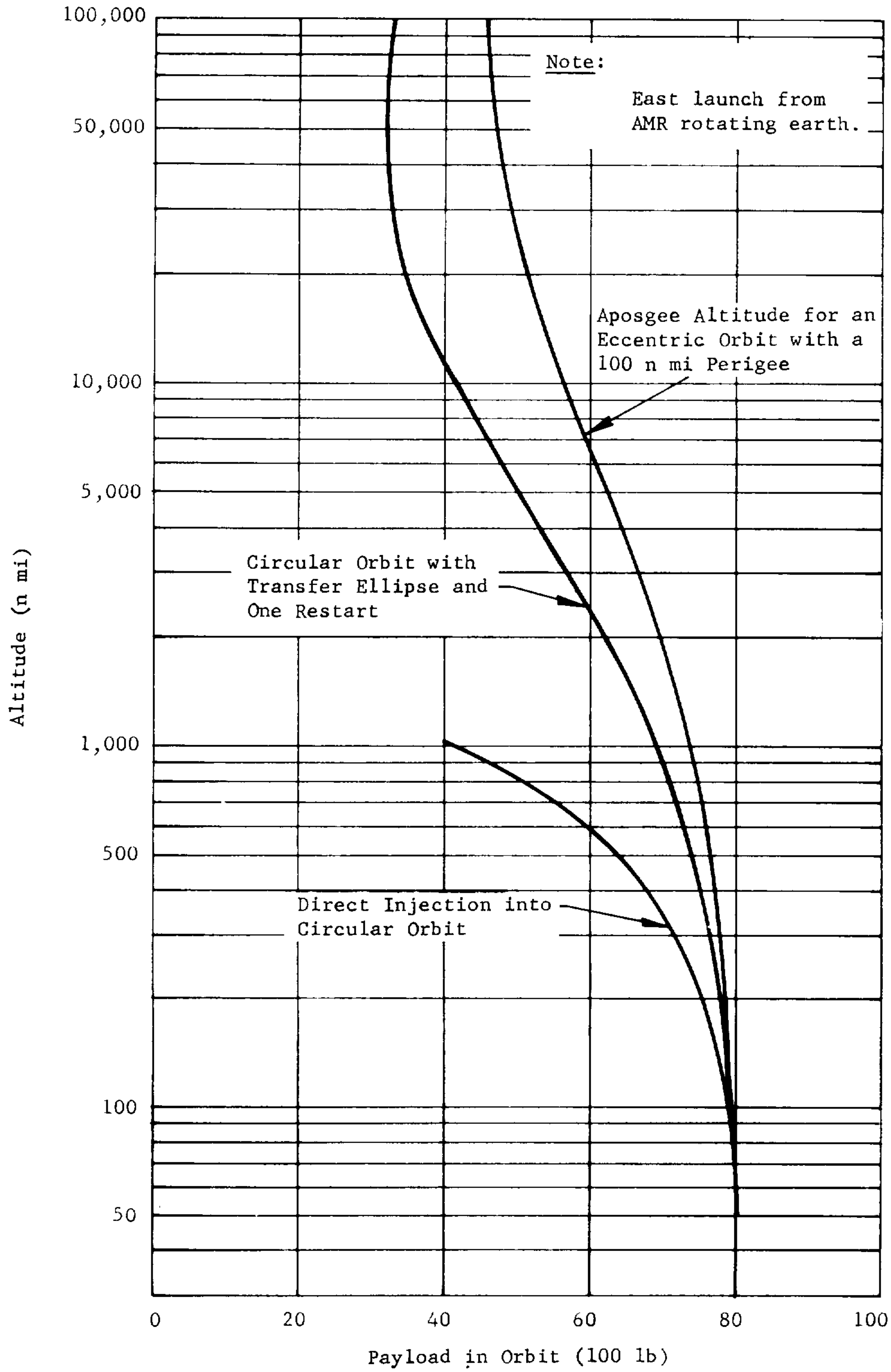

Fig. IV-3 Variation of Payload in Orbit with Altitude, Saturn S-I, S-II/Nuclear

The time histories of altitude, velocity, acceleration, and range are shown in Figures IV-4 through IV-7 for both configurations. These time histories are for the escape mission of the Saturn S-I, S-II/Nuclear and the 100-300 n mi eccentric orbit for the Saturn S-I/Nuclear. The payload for the Saturn S-I/Nuclear is 32,795 lb for the 100-300 n mi eccentric orbit.

C. CONFIGURATION

The nuclear R&D and operational step configurations and detail design are identical except that the operational propellant tank is longer. This duplication of structure insures that data obtained from R&D captive and flight tests are directly applicable to the operational nuclear step design.

Aluminum (2014-T6) is used for all structures. This alloy was chosen because of its weldability, high strength-to-weight ratio, and small loss of ductility at cryogenic temperatures. Past experience with this material has proved its versatility and reliability for chemical booster fabrication. A table of comparative values is shown in Volume II.

A tubular aluminum truss is used for support of the nuclear engine. The truss members are attached to the aft tank skirts and transmit engine thrust into the skirt through six longerons. The turbopump assembly and vernier control system nozzles are supported by the truss. This type of structure simplifies the problems of engine handling, access for maintenance, replacement, and repair. The total radiation of the reactor generates heat internally in materials near the reactor so that they must be cooled continuously during reactor operation. To maintain a temperature below 300°F in the engine truss, the lower third of the truss is cooled by flowing liquid hydrogen from the turbopump to the engine through the lower truss members. The upper truss members are uncooled since they are farther from the reactor. An engine compartment layout is presented in Figure IV-8.

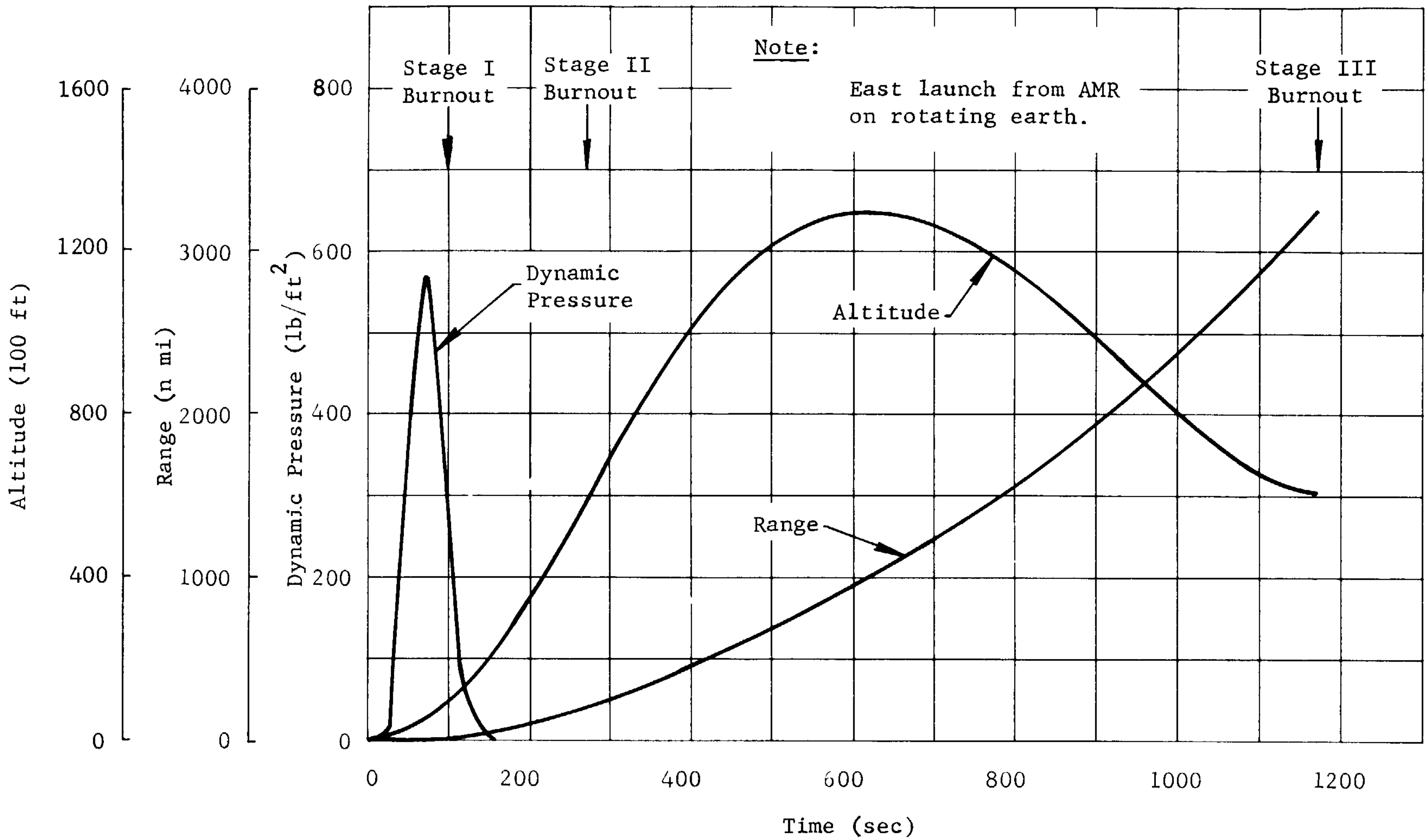

Fig. IV-4 Variation of Altitude, Range, and Dynamic Pressure with Time, Saturn S-I, S-II/Nuclear

[redacted]

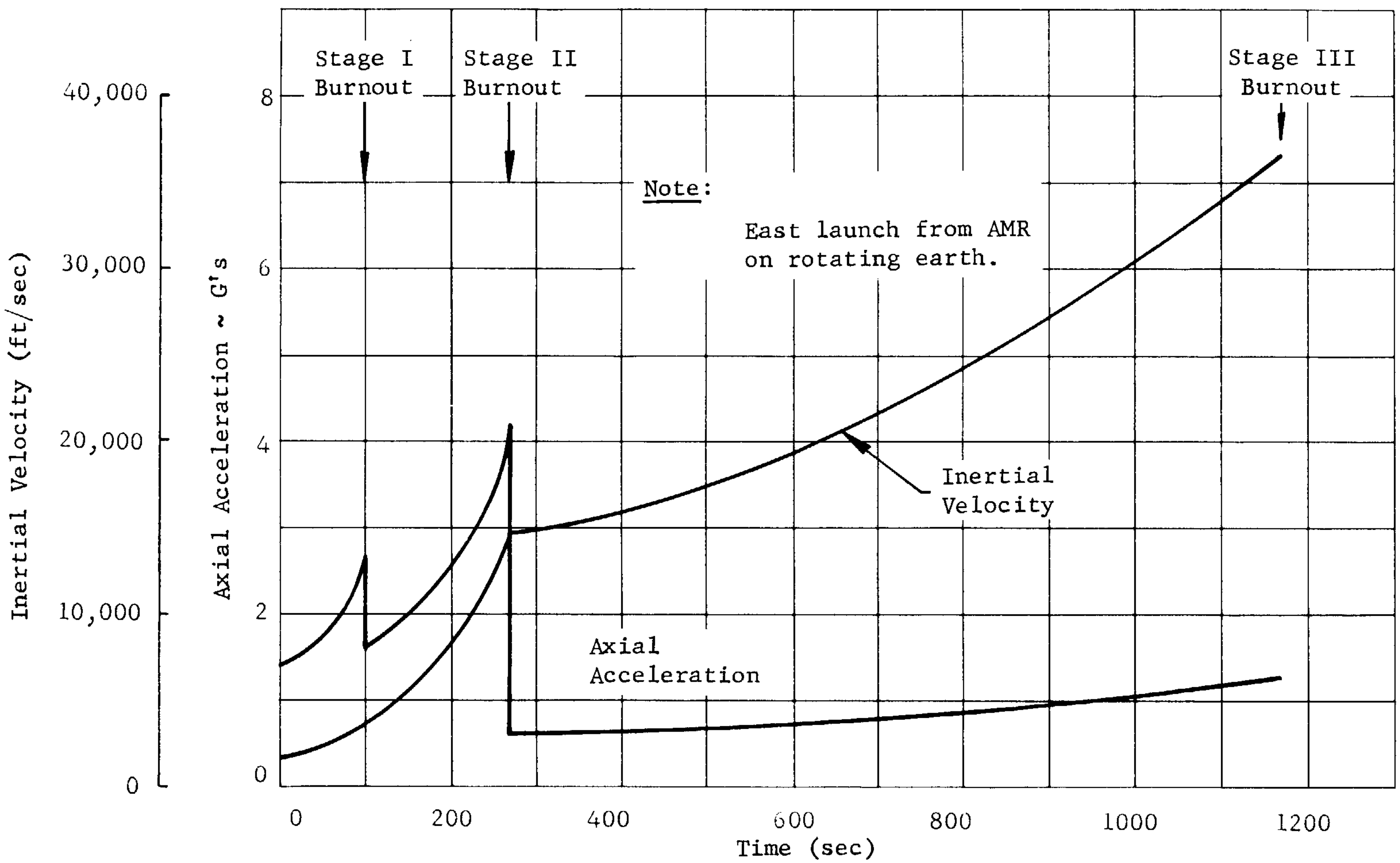

Fig. IV-5 Variation of Inertial Velocity and Axial Acceleration with Time, Saturn S-I, S-II/Nuclear

[redacted]

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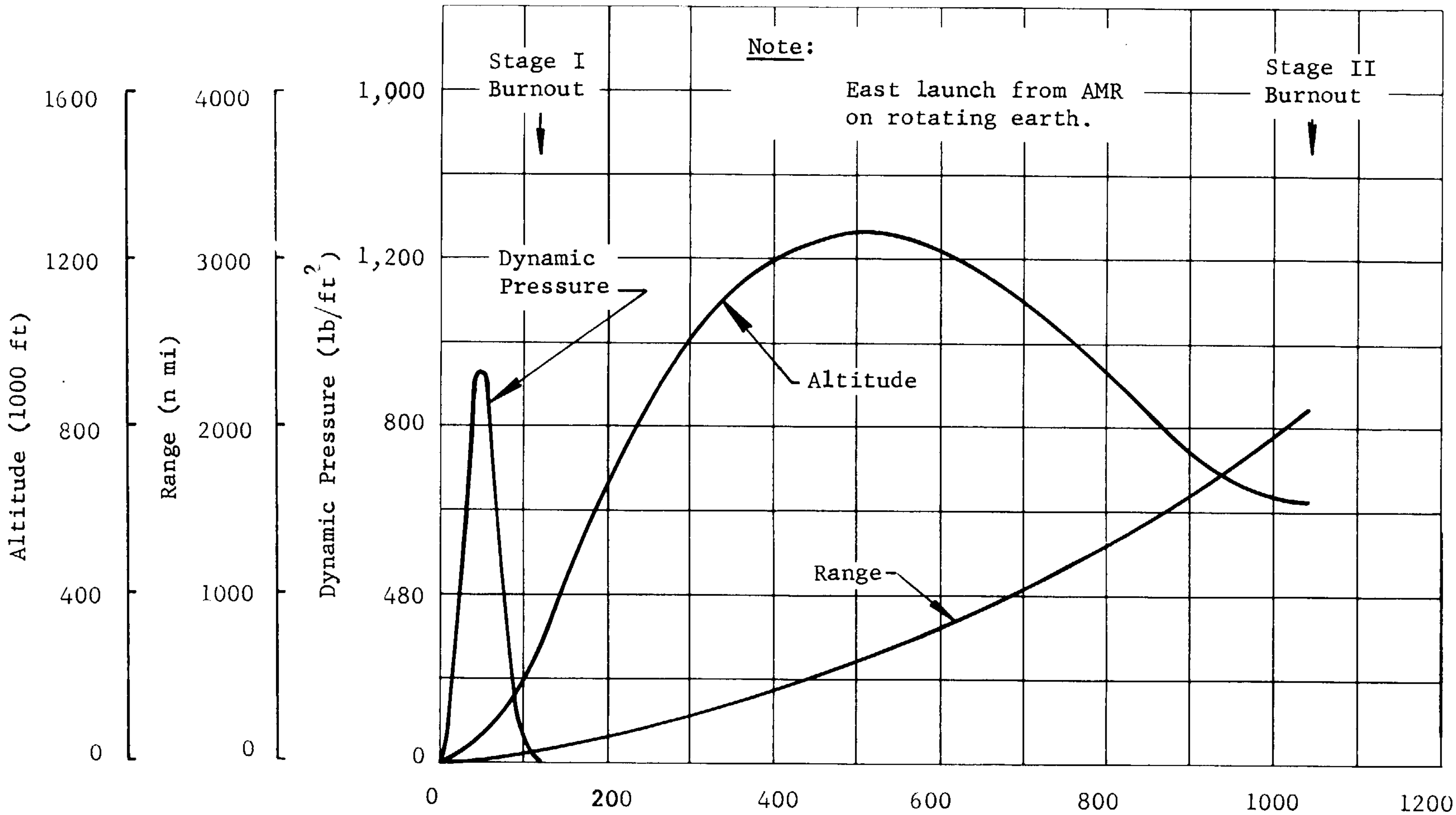

Fig. IV-6 Variation of Altitude, Range, and Dynamic Pressure with Time, Saturn S-I/Nuclear

[redacted]

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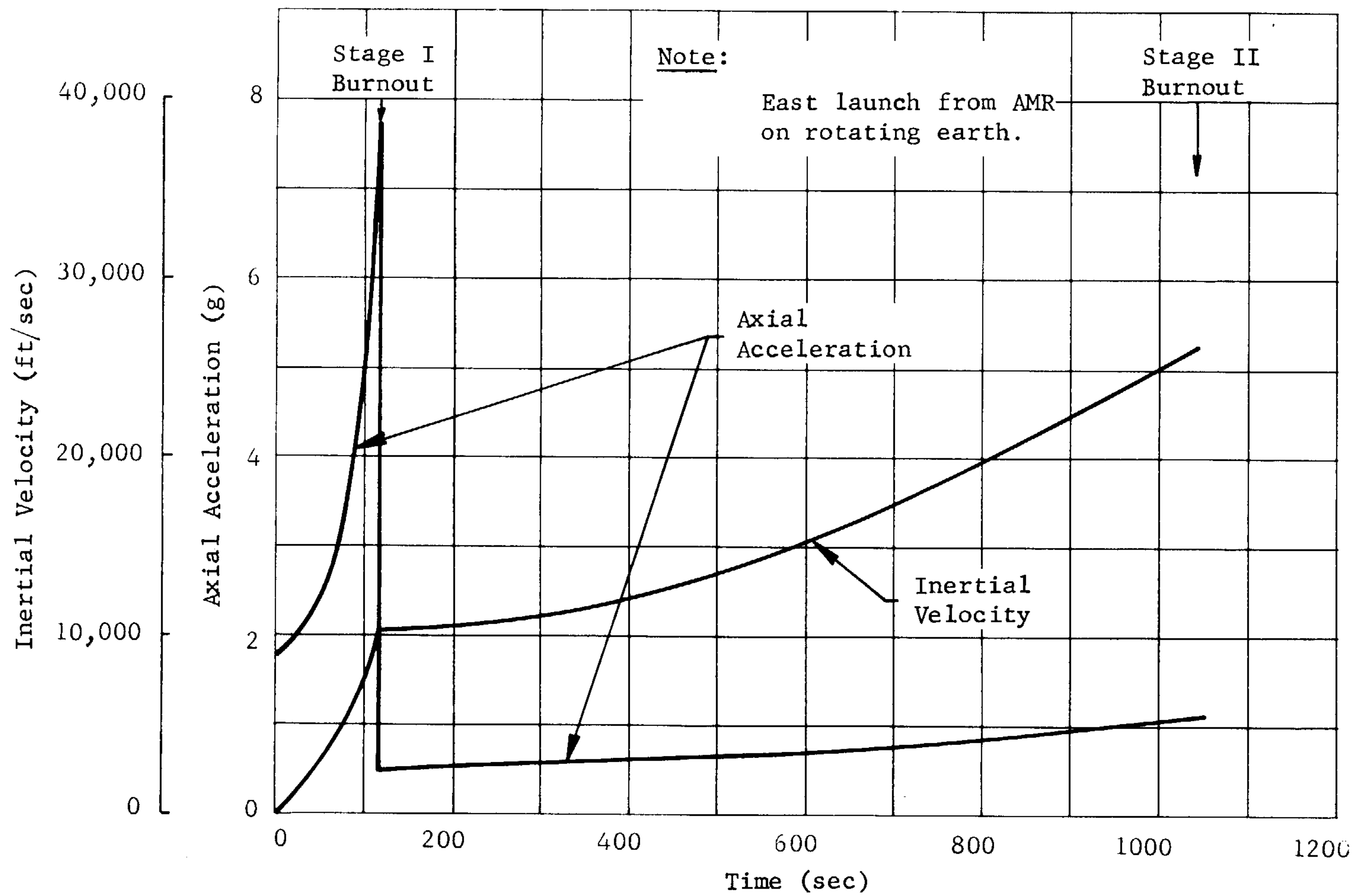

Fig. IV-7 Variation of Inertial Velocity and Axial Acceleration with Time, Saturn S-I/Nuclear

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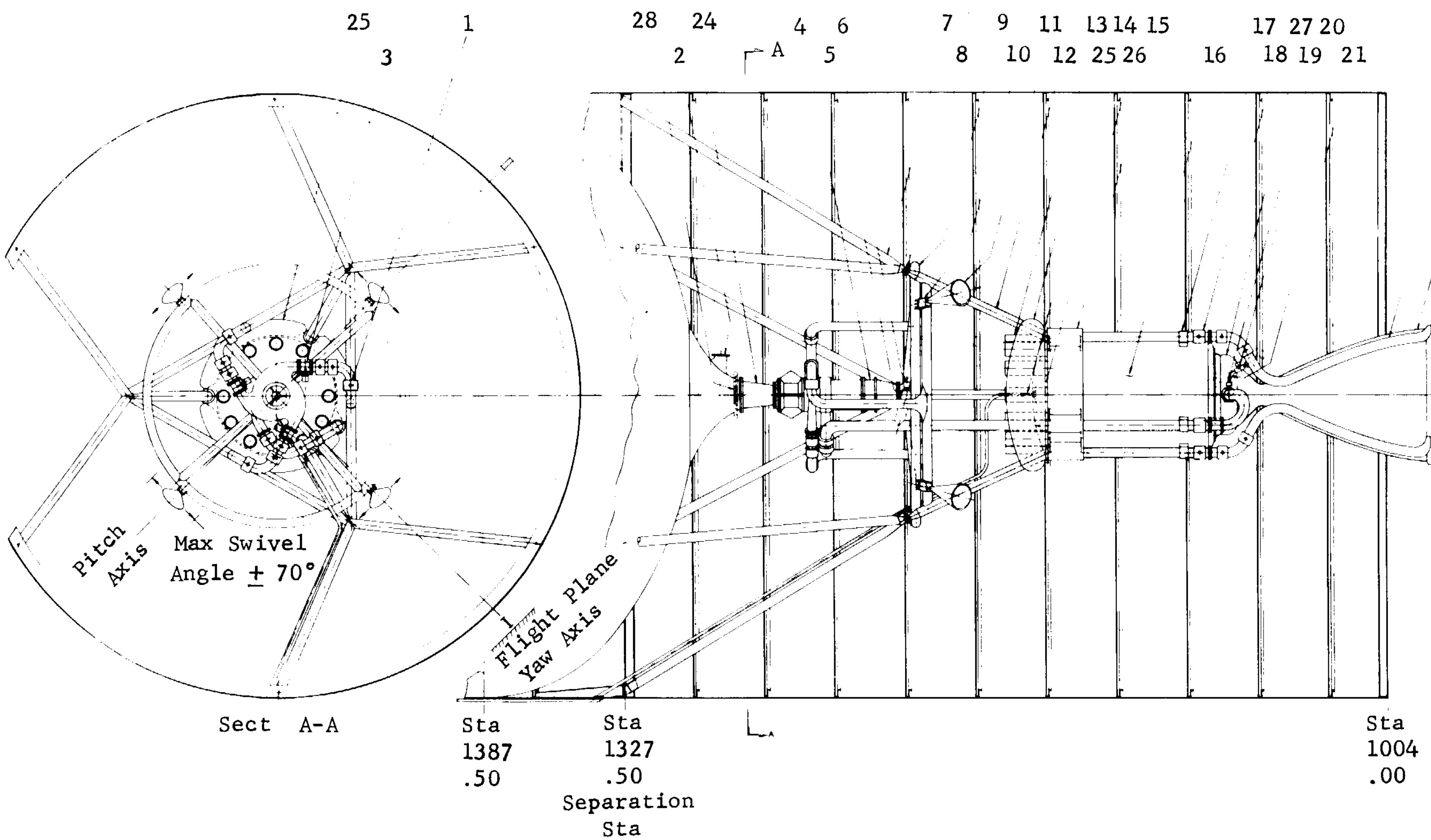

LEGEND:

28	OMEGA JOINT	15	THRUST RING
27	BLEED GAS COLLECTION MANIFOLD	14	PRESSURIZATION LINE
26	INSULATION	13	CONTROL ROD
25	RADIATION SHIELD	12	COOLED TRUSS
24	BOOST PUMP	11	CONTROL NOZZLE
23	THRUST CHAMBER NOZZLE (F = 40)	10	CONTROL NOZZLE ACTUATOR
22	HYDROGEN FEED LINE	9	EXHAUST DISTRIBUTION TORUS (VERNIER)
21	HYDROGEN BYPASS LIME (COOLANT)	8	ENGINE ALIGNMENT FITTING (BALL) (3)
20	HYDROGEN BYPASS VALVE (COOLANT)	7	UNCOOLED TRUSS
19	EXPANSION JOINT	6	TURBINE GAS BYPASS VALVE
18	UNIVERSAL JOINT (9)	5	TURBINE GAS BYPASS LINE
17	SUPPORT	4	TURBO PUMP ASSEMBLY
16	THRUST CHAMBER	3	PROPELLANT VALVE (3)
		2	HYDROGEN FILL AND DRAIN
		1	UNIVERSAL JOINT (12)

Fig. IV-8 Engine Compartment Layout

The aerodynamic, bulk, and recirculation heating values and the trapped gas weight, were established. Optimum tank configurations were designed to show the effects of pressure, temperature, and acceleration loads on tank weight. For a nuclear stage configuration using an ordinary water shield, the values of tank, shield, pressurizing gas, and interstage weights were optimized for various separation distances and propellant temperature rises. The minimum weight occurs with an elliptical tank bottom, a total propellant temperature rise of 3°F, a water shield weight of 1760 lb, and an engine upper-face tank-bottom distance of 12.3 ft.

The tank barrel walls are chem-milled to a shallow waffle cross-section for compression stability. All tank and skin panel splices are butt welded. The forward and aft tank skirts and the chemical-to-nuclear interstep structure (which is considered part of the Saturn S-I step) are stiffened with frames and stringers riveted to the skin. Inboard and structural profile drawings are shown in Figures IV-9 through IV-12. Flight weights are presented in Tables IV-2 and IV-3.

All structure is designed for an ultimate load factor of safety of 1.25 and a yield factor of 1.0, and is capable of withstanding prelaunch wind loads with any combination of payload and propellant loading. No tank pressure is required to stabilize the tank wall for this condition. The tank skins were designed for a pressure of 31 psig, which represents the required NPSH at nuclear stage start, plus the vapor pressure rise due to nuclear heating of the propellant. A prelaunch condition with payload attached, zero tank pressure differential, a 40 mph wind, and a 1.6 gust factor causes a compression load that dictates the tank skin waffles design. Tank skirts and the interstage structure are designed for the first-stage burnout condition on the R&D version and for the maximum $q\alpha$ condition on the operational version. The engine truss design is dictated by the engine thrust of the operational configuration. The effect of aeroelasticity was evaluated for the maximum $q\alpha$ condition. Its contribution to the total loading is less than 5%. The dynamic loads due to launch transients were less than the maximum $q\alpha$ loads for all parts of the missile. Handling and erection loads were analyzed and were not critical for any portion of the structure.

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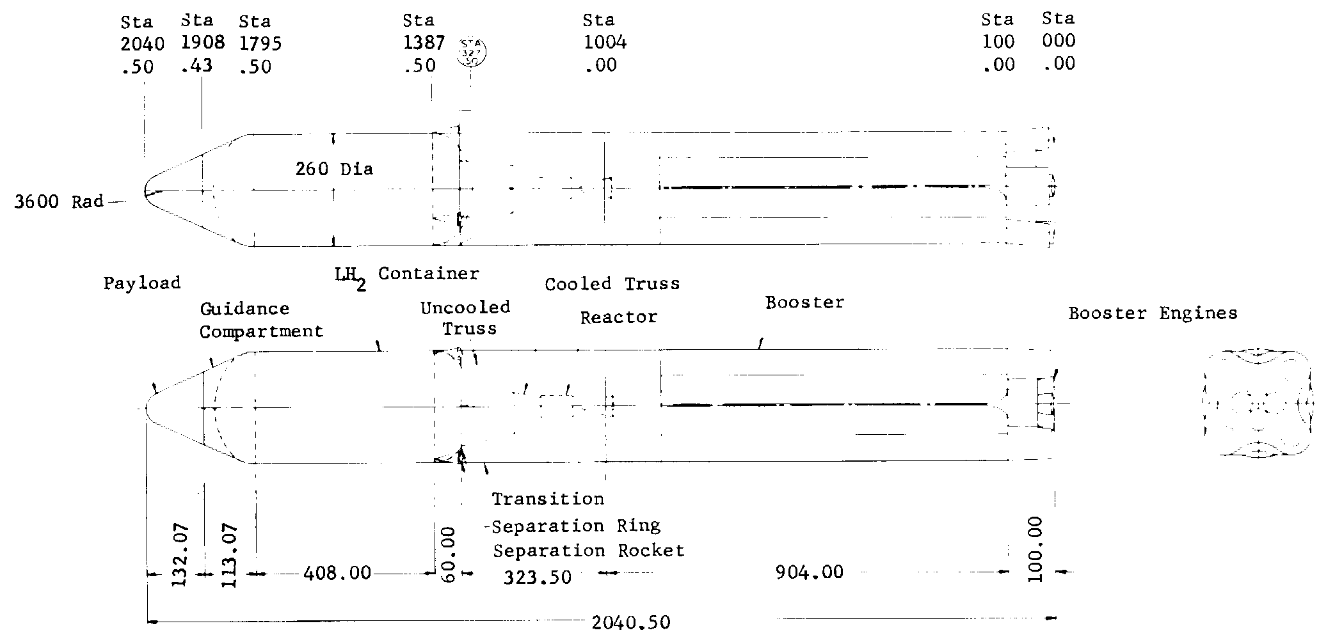

Guidance Compartment

<u>Transmitter Equipment</u>
- (2) Transmitter
- (4) Multiplexer and Decoder
- (2) Program Board
- (2) Vibration Analyzer
- (1) Antenna Multiplexer
- (4) Antenna Batteries

<u>Guidance Equipment</u>
- Stabilized Platform
- Computer
- Power Supply

<u>Miscellaneous</u>
- Umbilical Connector
- Access Doors
- Hydrogen Vent Valve
- Hydrogen Contains Pressure Valve
- Payload Separation Ring
- Droppler Antennas (Range Safety)
- Junction Box
- Rate and Pulse Beacon (Range Safety)
- Instrumentation (Range Safety)

<u>Nuclear Engine Compartment</u>
- Cooled Truss
- Uncooled Truss
- Transition
- Reactor
- Separation Ring
- Separation Rocket (3)

<u>Booster Skirt Area</u>
- Fuel Fill and Drain
- Oxidizer Fill and Drain
- Booster Engines

<u>Miscellaneous Items</u>
- Liquid Hydrogen Container (Nuclear Stage)
- Oxidizer Container (Booster)
- Fuel Container (Booster)
- External Pressurization Line
- External Conduit
- Destruct System (Booster)
- Destruct System (Nuclear)
- Umbilical Connector (Booster)

Fig. IV-9 Inboard Configuration - Two Stage Saturn/Nuclear

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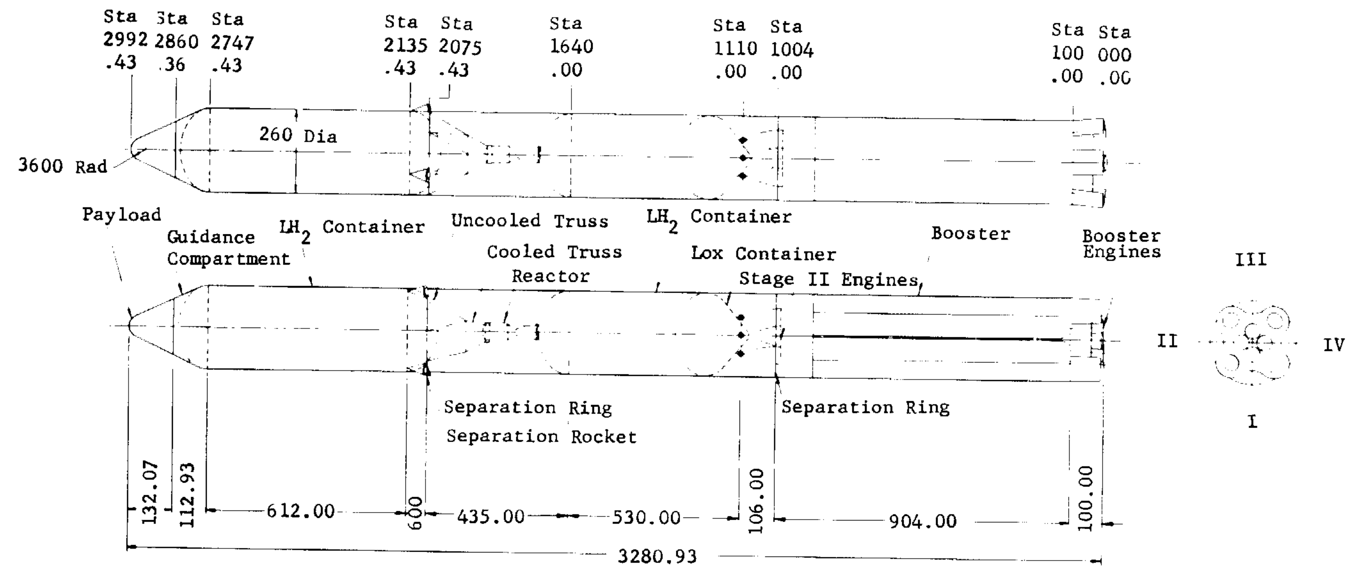

Guidance Compartment

Transmitter Equipment
- (2) Transmitter
- (4) Multiplexer and Decoder
- (2) Program Board
- (2) Vibration Analyzer
- (1) Antenna Multiplexer
- (4) Antenna Batteries

Guidance Equipment
- Stabilized Platform
- Computer
- Power Supply

Miscellaneous
- Umbilical Connector
- Access Doors
- Hydrogen Vent Valve
- Hydrogen Container Pressure Valve
- Payload Separation Ring
- Droppler Antennas (Range Safety)
- Junction Box
- Rate and Pulse Beacon (Range Safety)
- Instrumentation (Range Safety)

Nuclear Engine Compartment
- Cooled Truss
- Uncooled Truss
- Transition
- Reactor
- Separation Ring
- Separation Rocket (3)

Booster Skirt Area
- Fuel Fill and Drain
- Oxidizer Fill and Drain
- Booster Engine

Miscellaneous Items
- Liquid Hydrogen Contains (Nuclear Stage)
- Oxidizer contains (Booster)
- Fuel Contains (Booster)
- External Pressurization Line
- External Conduit
- Destruct System (Booster)
- Destruct System (Nuclear)
- Umbilical Connector (Booster)

Fig. IV-10 Inboard Configuration - Three Stage Saturn/Nuclear

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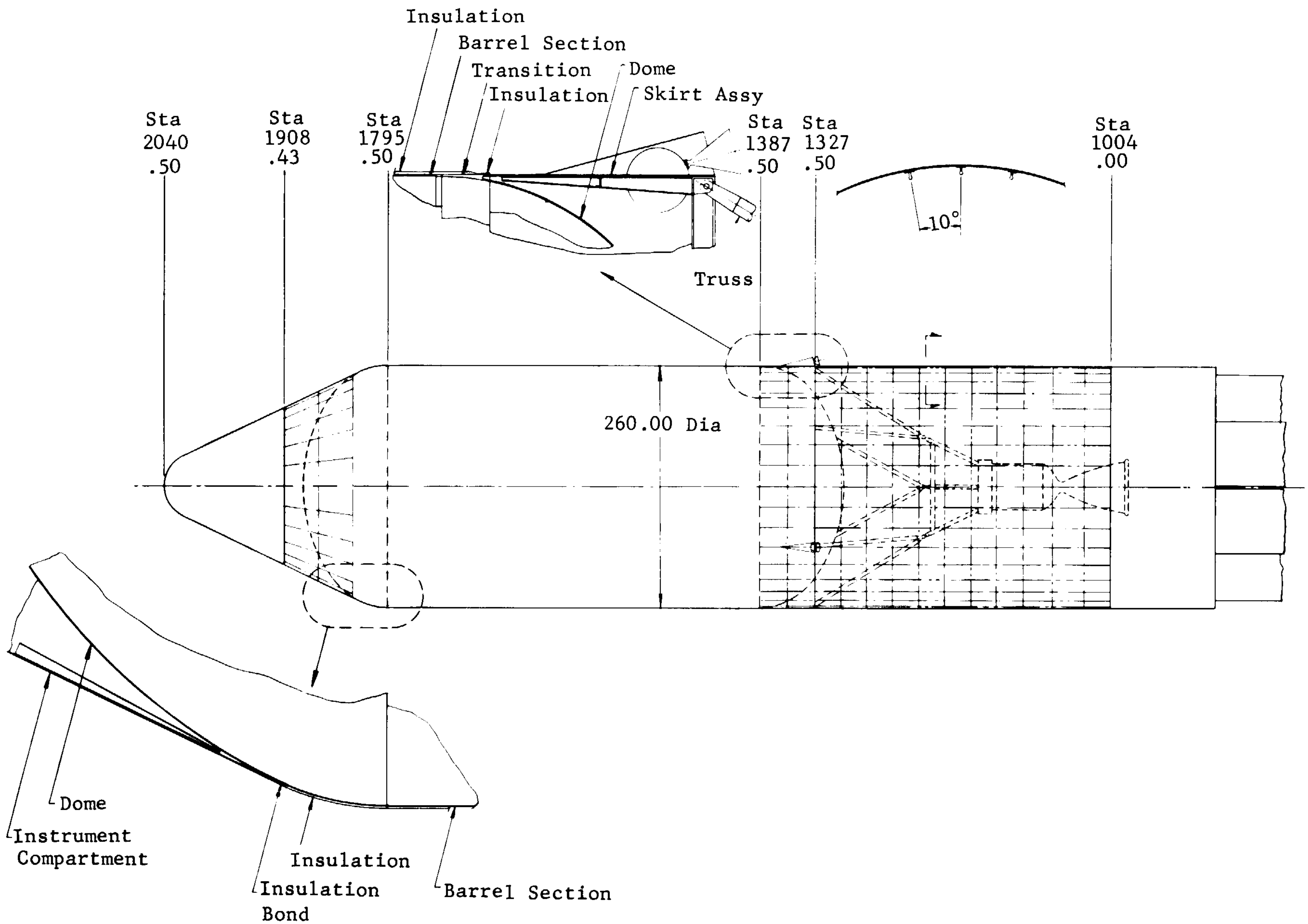

Fig. IV-11 Structural Arrangement - Two Stage Saturn/Nuclear

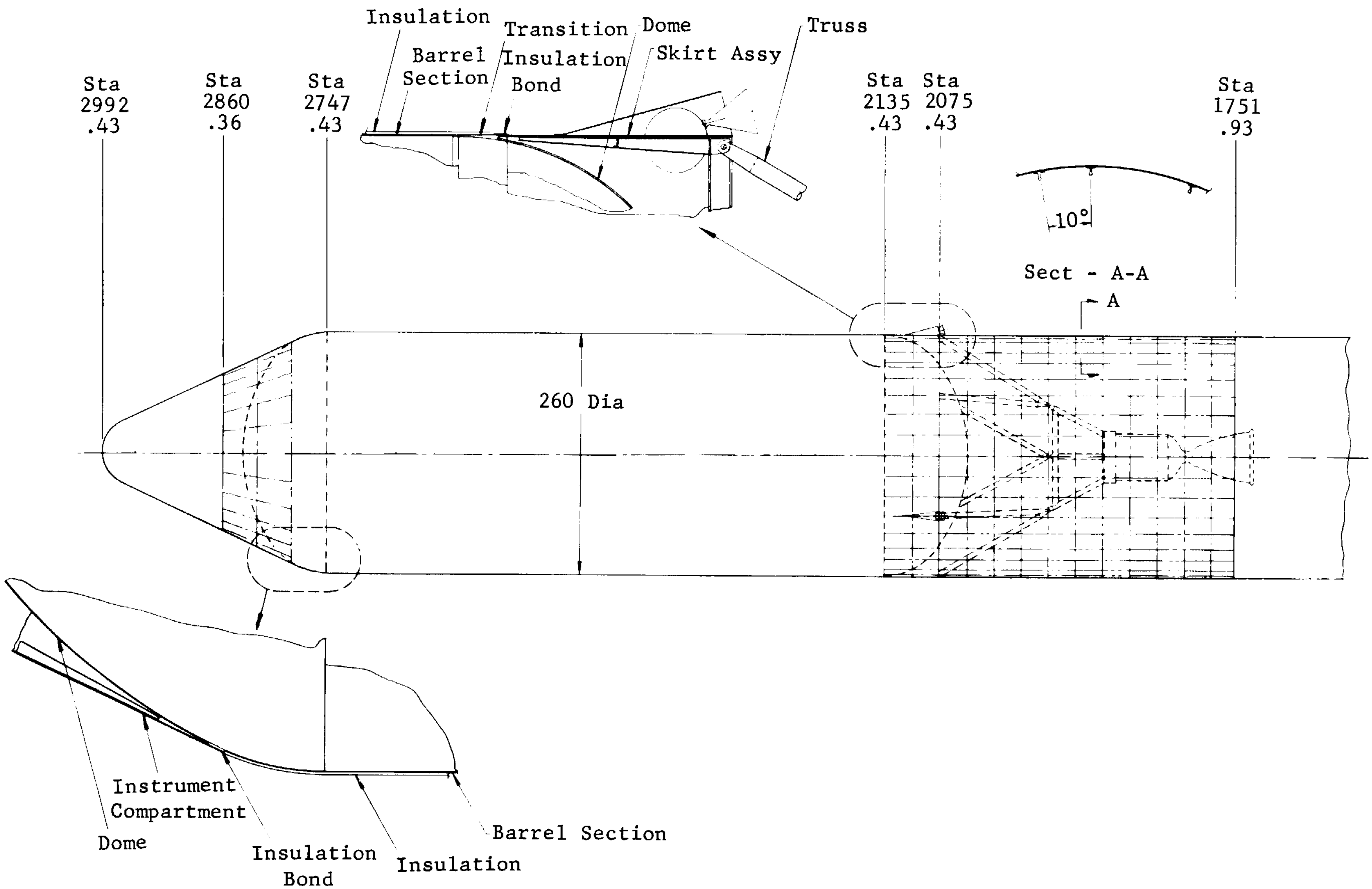

Fig. IV-12 Structural Arrangement - Three Stage Saturn/Nuclear

Table IV-2. Saturn Stage I and Nuclear Weights

Item	Step I (lb)	Nuclear Stage (lb)
Structure	57,800	5,456
Insulation	--	677
Propulsion	22,000	9,920
Equipment	2,500	1,200
Dry Weight Total	82,300	17,253
Payload	--	32,795
Trapped Propellant	15,000	920
Pressure Gas	*	383
Usable Residuals	6,500	--
Burnout Weight Total	103,800	51,351
Usable Propellant	684,620	65,000
Separation Propellant	--	249
Start Weight Total	788,420	116,600

Missile Flight Weights

Liftoff	905,020
Stage I Burnout	220,400
Stage II Start	116,600
Stage II Burnout	51,351

*Included in trapped propellant weight

Table IV-3. Saturn Stage I, II, and Nuclear Weights

Item	Step I (lb)	Step II (lb)	Nuclear Stage (lb)
Structure	55,000	16,390	6,875
Insulation	--	--	866
Propulsion	22,000	9,630	9,920
Equipment	2,500	500	1,200
Dry Weight Total	79,500	26,520	18,861
Payload	--	--	42,640
Trapped Propellant	15,000	3,290	920
Pressure Gas	*	*	530
Usable Residuals	6,500	6,730	--
Burnout Weight Total	101,000	36,540	62,951
Usable Propellant	587,540	324,920	90,000
Separation Propellant	--	--	249
Start Weight Total	688,540	361,460	153,200

Missile Flight Weights

Liftoff	1,203,200
Stage I Burnout	615,660
Stage II Start	514,660
Stage II Burnout	189,740
Stage III Start	153,200
Stage III Burnout	62,951

*Included in trapped propellant weight

Of the two vehicles recommended, the R&D vehicle is subject to the most severe aerodynamic heating. The accompanying tabulation compares the thrust-to-weight ratio and the heating indicator ($1/2 \int \rho V^3 dt$) of the two configurations.

Vehicle	Thrust/Weight	$1/2 \int \rho V^3$ (Max $q\alpha$)	$1/2 \int \rho V^3 dt$ (Stage I Burnout)
R&D	1.67	2.35×10^7	8.037×10^7
Operational	1.25	1.237×10^7	3.488×10^7

The maximum temperatures for the R&D vehicle encountered during the boost phase were determined for the stagnation point, sonic point, a point midway on the cone skirt, and the corkboard insulation for zero angle of attack. These values are shown in the accompanying tabulation.

Location	Material	Thickness (in.)	Maximum Temperature (°F)
Stagnation Point	Fiberglas (91-LD)	0.09	525
Sonic Point	Fiberglas (91-LD)	0.09	615
Cone Skirt	Aluminum	0.032	735
Insulation	Corkboard	0.125	260

Other temperature points which are critical are on the transition section just aft of the insulation, on the cone skirt near the skirt-tank shoulder, and along the surface of the liquid hydrogen tankage. For the nose cone shape considered, the calculated maximum temperature on the nose cone skirt is unacceptable and would require the application of insulation or a thin ablative coating of Emerson Electric "Thermo Lag" material.

The nose shapes shown were not optimized in regard to cone angle and nose radius since the payload shape is not explicitly defined. Rounding of the cone-cylinder junction was incorporated to minimize local flow separation and buffeting effects.

A dynamic staging analysis was performed to indicate the feasibility of using auxiliary rockets on the nuclear stage to effect separation. The problem is unusually difficult for the RIFT application because of the long transition structure or skirt required between the nuclear and chemical stages. However, it was found that separation rockets totaling 16,000 lb thrust for 4 sec would result in safe clearance from the chemical stage. A complete fire-in-the-hole staging analysis was not performed, partly because of lack of information on the slow thrust buildup of the nuclear engine and because of the need for experimental data on internal gas flow for the actual compartment configuration. However, a preliminary analysis of the interstage compartment venting required for practical fire-in-the-hole staging was made and resulted in a vent area of 60 ft^2. This vent area does not appear to be difficult to incorporate in the interstage structure.

The S-II stage will be designed for three-stage operation (not involving RIFT), which will have a high dynamic pressure staging condition similar to that of the RIFT. No further problems are anticipated that would require an extensive study of stage separation between the S-I and S-II Saturn stages.

D. GUIDANCE AND CONTROLS

1. Guidance

The guidance system requirements for mission flexibility in the RIFT program are accomplished by an inertial guidance system. This system uses the high accuracy components that will be available in the 1965 to 1970 period. The following component accuracies are required for the guidance system:

Platform alignment	6.0 sec of arc
Gyro drift-torque unbalance	0.015 deg/hr
Accelerometer residual drift	1.0×10^{-5} g
Accelerometer scale factor error	1.0×10^{-5}
Computer quantization error	0.042 ft/sec

The gyro and accelerometer accuracies represent a factor of two improvement over present-day equipment while the computer accuracies represent a factor of four improvement.

The system develops velocity data at burnout to less than 0.25 ft/sec, which results in a CEP of 0.5 n mi for the ballistic lob shots. The guidance system provides RIFT with burnout velocity and position cutoff accuracies of ±2.5 ft/sec and ±250 ft, respectively, for orbital injections and escape missions.

A three-gimbal platform will be adequate for RIFT with the pitch gimbal having a 200-deg-of-gimbal freedom.

2. Flight Controls

A self-adapted autopilot is recommended for the RIFT program. This control system has been chosen instead of a linear system because it will be available through prior development in the Saturn program. This autopilot possesses the following advantages:

1) Flexibility,
    a) Payload changes,
    b) Trajectory variations,
    c) Mission changes,
        (1) Two-stage vehicle,
        (2) Three-stage vehicle;
2) Perform necessary information processing,
    a) Provide for displacement and rate gain change for required system stability and performance throughout the trajectory,
    b) Provide filtering and adjustment of filter parameters for cancellation of low bending frequencies for stability throughout the trajectory.

The nuclear stage by itself has structural bending characteristics that can be stabilized by conventional methods. Since the adaptive portion of the autopilot will be in the nuclear stage, it will also be used to control and stabilize this stage.

Compensation of the lower structural frequencies will be achieved by using an adaptive portion of the control system that continuously monitors the rigid body, first and second mode frequencies; makes continuous variations to the displacement and rate gains; and supplies direct cancellation of the bending response at these frequencies. Additional cancellation will be made available for the higher mode structural feedback, or compensation will be accomplished by conventional filtering, depending on the autopilot used. The adaptive equipment makes continuous variations to the control system parameters to adjust to the environment that the missile is subjected to; i.e., changes in dynamic pressure, moment of inertia, and modal frequencies. The description and analysis of the self-adaptive autopilot for the RIFT missile configurations are presented in Volume II.

The booster using Saturn S-I, a 260 in. diameter hydrogen S-II second stage, and the nuclear third stage has a first structural bending mode frequency of 0.837 cps and a second structural bending mode frequency of 2.74 cps at launch. Adequate margins of 10 db for gain and 30 deg of phase are provided to stabilize and control the missile. The gains to stabilize the missile are adequate to fly through the wind shear profile. The first bending mode frequencies of the nuclear stage by itself for the various configurations studied range from 5.04 cps to 16.14 cps for full-loaded condition.

The thrust vector control for the nuclear stage is provided by four vernier nozzles. A total thrust of 2600 lb is required on the nuclear stage in the two-stage configuration. The nuclear stage requires 3600 lb thrust when used in the three-stage configuration. The vernier nozzles are canted out 20 deg to eliminate flame impingement on the nuclear engine. The vernier nozzles swivel ±70 deg. The thrust misalignment moment (due to the nuclear engine) is balanced out when the two vernier nozzles are swiveled to 30 deg in the pitch and yaw planes. The additional 40 deg are used for control of the missile and will give an angular acceleration of 0.022 rad/sec^2 for the nuclear stage of the Saturn two-stage configuration, and an angular acceleration of 0.01 rad/sec^2 for the nuclear stage of the Saturn three-stage configuration.

[redacted]

An electromechanical rotary-type actuator, operating through a gear reducer, is employed for thrust vector control of the four vernier engines on the nuclear stage. Two vernier nozzles are swiveled for pitch control, two for yaw control, and all four provide roll control. The maximum load of each actuator is provided by a 2-hp electric motor.

E. ELECTRICAL

The nuclear booster electrical power requirements have been divided into three categories: (1) APS system, (2) IPS system, and (3) VED (vernier electric drive) system. All of these requirements are met by a 28v dc power source. The APS system and IPS system require electrical power for 1200 sec after T-0, while the VED system requires power for 900 sec after separation of the nuclear booster from the second stage.

Various alternatives for a d-c power source were considered during this study. The two systems that appear feasible to meet these power source requirements were batteries or rectifiers with an a-c input supplied by an alternator powered by a hot gas turbine or motor. Both systems have proved reliable.

The battery power source is recommended for all three power source applications. The type of battery to meet these requirements is the primary automatically activated silver-zinc battery. The prime reason for the selection of the battery system is its lower cost. In addition, extensive missile experience with the recommended battery supply system has demonstrated a high degree of reliability. The estimated watt-hour demand, weight, and volume for each system are as follows:

	Power (wh)	Weight (lb)	Volume (in.^{3})
APS	320	21.3	405
IPS	614	41.0	780
VEDS	1590	106.0	2025

These estimates are based on the average power requirements for each of the electrical systems.

[redacted]

F. INSTRUMENTATION

Two low-level pulse code modulated/frequency modulated (PCM/FM) sets are provided in all R&D vehicles. There are approximately 550 different instrumentation measurements required for the whole program, but no more than 404 will be made on any one test. This consists of 392 analog channels and 12 channels of digital bilevel data. The telemetry equipment is located forward of the nuclear stage and is well shielded by the liquid hydrogen tank. The instrumentation will handle both the nuclear stage and booster measurements. The airborne equipment consists of transducers, signal conditioners, power supplies, program board, PCM/video telemetry package, and vibration spectrum analyzers. The PCM/video unit accepts 196 low-level analog inputs and six digital inputs and converts these data into a serial, nonreturn-to-zero (NRZ) binary code.

The 1-σ system accuracy is 0.3%. Two of four inputs of the same sampling rate may be connected in parallel externally to effectively increase the sampling rate to 800 or 1600 samples per second. The system accuracy will be slightly less in this case, however, with a 1-σ error not exceeding 0.4%.

By using a nine-channel high-frequency vibration spectrum analyzer, the many FM/FM channels now required in existing systems may be eliminated by compressing the bandwidth and sampling with the PCM/FM system. The vibration spectrum analyzer accepts randomly varying 100-2000 cps voltages generated by vibration acceleration, (g), sensing transducers, and converts the information into a slowly varying voltage which corresponds to the function $\sqrt{g_{rms}/cps}$. A 75-cps bandwidth filter is swept through the spectrum to be analyzed at variable rates of 2, 4, or 6 sec per sweep.

The IRIG (Inter-Range Instrumentation Group of the Department of Defense) recommends use of the 2200 mc (UHF) bands after 1970 and, accordingly, all test ranges are in the process of converting to these frequencies. While the present 220 mc (VHF) bands may still be available, the various range instrumentation plans call for change of equipment to receive only UHF channels. Accordingly, it is recommended that the UHF bands be employed for this program.

[redacted]

Following the trend established in the KIWI tests, provision for internal reactor sensors will be made. The core and reflector will be instrumented with thermocouples. Pressure and displacement transducers are also to be used in the reactor. Tungsten-rhenium thermocouples with a coating of beryllium oxide, hydride, or nitride, and a center of beryllium are used.

Instrumentation is provided to determine dangerously high neutron flux or a rate of change of flux which would, in a short time, lead to dangerous levels. Instrumentation is included to detect plugged fuel channels and pump or control power failure; a sudden appearance of greater than normal radio activity in the coolant or space around the reactor; loss of control rod motors; loss of instrument air pressure; broken wires in safety circuits; or failure of all thermocouples or flow indicators in any one flow channel.

The recommended instrumentation system is a PCM telemetry link that provides the following characteristics:

1) A better than ten-fold increase in accuracy over an analog system;

2) A significant savings in instrumentation costs;

3) The elimination of underground instrumentation signal conditioning;

4) The opportunity of moving the blockhouse a considerable distance from the test stand for safety reasons;

5) In the event of a disaster on the stand, reactivation time and costs would be reduced;

6) A significant increase in reliability;

7) Tried and proved off-the-shelf hardware.

Provision will be made for the use of two coaxial transmission lines to interconnect the test vehicle and instrumentation center. One line will carry the serial coded digital output, the other will carry the RF serial coded signal. These two circuits will be used as backup until more definitive information is available on the potential radiation blackout that may occur in an RF path as a result of ionized fields of gaseous matter.

[redacted]

The use of PCM techniques with presently developed and available components such as encoders, transmitters, receivers, etc, represents a significant step forward in instrumentation techniques. Direct coupling via the RF link and a hard wire metallic circuit from the encoder serial output is provided for backup.

All R&D and training flight missiles are equipped with a range safety system for shutdown or destruct of any errant missile. This equipment consists of a dual command receiver system, antennas for the command receivers and tracking system, a tracking transponder with associated filter, and destruct circuitry to operate the initiators and associated destruct mechanisms.

The MISTRAM (missile trajectory and measurement system) is used to determine the position and velocity of the missile in flight.

G. RADIATION EFFECTS

The radiation environments were examined both in the region around the reactor and at the vehicle nose cone. During full power operation, the reactor engine of a nuclear vehicle is an intense source of both neutron and gamma radiation. The radiation has complex effects on the electronic components, mechanical devices, lubricants, plastics, etc. which must be used throughout the vehicle.

The reactor radiation environment is relatively constant during the operation of the engine and constitutes a permanent damage threat to components such as control actuator motors and instrumentation sensors due to degeneration of lubricants, electrical insulation, etc, from both radiation and high temperature resulting from radiation heating.

The nose-cone radiation environment may be described as dynamic inasmuch as the shielding of both gamma and neutron radiation by the propellant is a decreasing factor as propellant is used. The increase of gamma dose rate and neutron flux at the nose cone is exponential until engine shutdown. At this time there is an abrupt drop in neutron and gamma flux to several orders of magnitude below the peak flux. The radiation flux after engine shutdown is composed of delayed neutrons and fission product-decay gammas, and constitutes an insignificant contribution to the environment.

The electronic systems, operating in the nose cone, contain semiconductor devices and other radiation-susceptible components. Permanent damage thresholds for the more sensitive of these devices, such as silicon power diodes and power transistors, are generally considered to exist at neutron-integrated fluxes of 10^{10} to 10^{11} neutron-cm^{-2} and about 10^{6} r of gamma radiation.

In many circuits, a disturbed condition is temporarily induced by the ionization phenomena in or around the active elements of the circuit during irradiation. This effect is temporary and roughly proportional to the dose rate of the radiation environment. The total effect on circuit or system functioning due to such temporary changes is difficult to access from the known responses of tested components since the effect on the system of all component responses would require detailed analysis and radiation environmental testing of equipment yet to be designed.

The study of the problem of radiation effects on the electronic and electromechanical equipment around the reactor and in the nose cone region of a nuclear vehicle may be summarized by the following general statements:

1) The integrated neutron fluxes and gamma radiation doses at the nose cone range from 6×10^8 to 3×10^9 neutron-cm^{-2} and 3×10^4 and 6×10^4, respectively, among the several vehicle configurations that were studied. These levels are not sufficient to cause permanent damage, even in the most susceptible components that might be used in this region, such as power transistors or semiconductor diodes;

2) The peak neutron flux and peak gamma dose rates at the nose cone range from 7×10^7 to 3.5×10^8 neutron-cm^{-2}-sec^{-1} and 34 to 78 r/sec, respectively. These are insufficient to cause serious disturbance of normal electronic equipment. There is, however, no way of validating this statement without hardware testing, since electronic systems are very individual in response to radiation dose rates;

3) The reactor radiation environment integrates a neutron flux and a gamma dose of 3×10^{14} neutron-cm^{-2} and 5×10^6 r, respectively, during the operating period. These levels are such that with proper choice of materials, electromechanical devices to be used in this region can be developed with useful lifetimes of many multiples of one reactor-operating period;

4) In the R&D phases of electronic and electromechanical system investigations the following special testing is suggested to qualify hardware for the radiation environments;

   a) System and subsystem testing of the nose cone electronics in pulse-radiation environments, which is necessary to establish the degree to which a temporary radiation effects problem exists;

   b) Testing of those specific materials and components that will be subjected to the high-temperature and high-radiation fluxes characteristic of the reactor region.

V. FACILITIES

A. MANUFACTURING

All structural fabrication processes for the RIFT program are conventional and are well within the state of the art. The Martin Company, Denver Division, is experienced in welding of 2014-T6 aluminum, chem-milling, metal forming and machining; and assembling riveted aluminum structures. Explosive forming of smaller tank domes has also been accomplished at Martin. Figure V-1 shows the major Martin-Denver facilities for the RIFT program.

1. Tooling and Manufacturing Philosophy

Hard tooling will be fabricated for the RIFT stage. This tooling is adaptable and, with very little rework, can be used for fabrication of an operational nuclear stage for large chemical boosters. This will permit the changeover from test to operational vehicles with minimum additional tooling.

The RIFT vehicle will be fabricated on a production line with subassemblies phased in at various control points to assure a smooth flow through the factory. The subassemblies will be fabricated at the same location as the final assembly. All structural assemblies will be fabricated by the RIFT contractor.

Martin-Denver will position, fabricate, and test all the GOE required for the launch site and the missile assembly building, and items of airborne electronic equipment such as the autopilot, telemetry transmitters, and command receivers.

No new major facilities would be required for test tooling, or airborne and ground electronics.

2. Major Production and Master Tooling Requirements

The major tools to be fabricated for the RIFT vehicle are broken down by major assemblies. The liquid hydrogen tank assembly will require several large tools. These tools are:

[redacted]

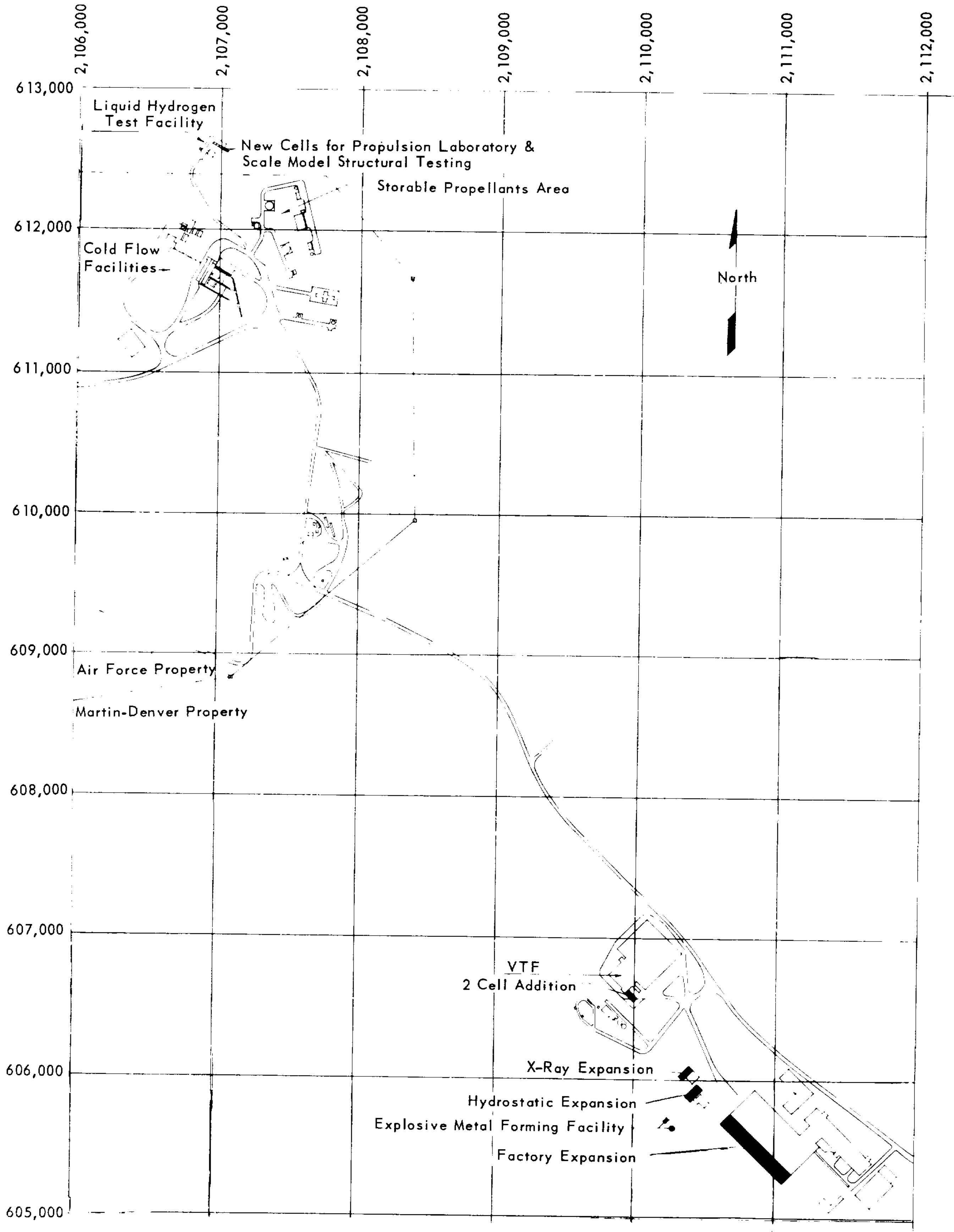

Fig. V-1 Martin-Denver Facilities

[redacted]

[redacted]

1) Barrel weld fixture - an internal welding tool with a 70-ft barrel and 21.67-ft diameter;

2) Rotation weld fixture - now in use for Titan, with an 80-ft tank length and 21.67-ft diameter capacity;

3) Dome explosive-form tool - a concrete tool built into the ground with a plastic-lined form and water tank as an integral part of the tool;

4) Dome-preform weld fixture - an automatic welding fixture to weld the cone-shaped part for the explosive-form tool;

5) Dome-outlet explosive-form tool - a conventional explosive-form tool made from steel for use in the explosive-forming facility;

6) Dome-outlet preform-weld fixture - an automatic welding fixture to weld a cone-shaped part for the explosive-form tool;

7) Outlet-to-dome weld fixture - an automatic welding fixture for welding the outlet to the dome.

The engine-support truss assembly will require the following tools:

1) Truss-welding fixture - a location and holding fixture for welding assemblies;

2) Engine-alignment fitting-machine fixture - a holding fixture for matching engine alignment balls.

The aft skirt assembly will require a trunnion fixture for location and assembly.

The major master tool requirements will be:

1) Ring master - transition to payload, interface master;

2) Ring master - transition to tank assembly, interface master;

3) Master model - forward dome;

4) Master model - aft dome;

[redacted]

5) Master gage - engine-support truss location;

6) Master model - engine-support truss;

7) Master gage - engine-support truss alignment fitting, control location;

8) Ring master - aft skirt tank, interface master;

9) Ring master - aft skirt to booster, interface master;

10) Master model - exhaust-distribution torus.

3. Processes

Explosive forming - The explosive-forming process has proved economically advantageous when used to produce extremely large shapes. This premise has been verified at Martin's explosive-forming test facility. Conventional commercial forming equipment currently available (including spinning machines) has limited size capability. Therefore, to produce large assemblies such as dome shapes with this equipment, multiple sections must be formed and joined together. There are many disadvantages to conventional fabrication, thus emphasizing the need for a better explosive-forming method. Explosive forming possesses unlimited energy potential and requires a minimum of supporting equipment. The basic techniques developed at Martin allow production of large components with increased structural integrity at considerable savings. Explosive forming of domes at the Martin facility indicates this economy trend in the production of large missile components.

Chemical milling - Chemical milling has proved very feasible and desirable for producing missile structural components that must vary in thickness to minimize weight. Martin's chem-milling facility will be used on the tank domes and tank barrel skins to provide proper material thicknesses. This process permits thinning the gage of the tank domes and tank barrel skins to the proper thickness for carrying structural loads, and simultaneously providing increased land thickness for the reduced material allowables in the welded areas. It is anticipated that the chem-milling will be limited primarily to the tank structure.

[redacted]

4. Hydrostatic Test

After fabrication, the tank will be pressure checked in a hydrostatic test facility to verify the tank's tightness and ability to meet the design pressure. The hydrostatic test for the RIFT tank will require a test pit and a wash pit. The test pit will be approximately 27 ft square and 95 ft deep. The test pit will contain a closed-circuit television system for monitoring the tank for leakage during the pressure test, welding equipment for on-the-spot welding repairs, equipment for pressure test and volume calibration of the tank, a personnel elevator, and a stand for supporting the tank during testing.

The wash pit will be approximately 25 1/2 ft in diameter and 95 ft deep. The wash pit will be equipped for washing and rinsing the interior and exterior of the tank, iriditing the tank, and for purging it with an inert gas.

The building housing the test and wash pits will be approximately 100x70x110 ft. Full-length doors in front of each pit will be required for erecting and lowering the tank. Doors will be required in the roof for lowering the tank into the pits, and for moving the tank from one pit to another. An A-frame hoist, mounted on tracks for fore and aft movement, with a track beam for lateral movement, will be required on top of this building. The hoist will require a hook height of approximately 90 ft above the top of the pits.

A typical cycle for movement of the tank through the hydrostatic test building would be:

1) Erect the tank using a hoist and erection dolly;

2) Pick up the tank and place it in the test pit;

3) Pressure test and repair leaks;

4) Calibrate the tank for volume;

5) Pick up and place the tank in the wash pit;

6) Wash with a mild alkaline solution;

7) Rinse with demineralized hot and cold water;

8) Iridite the tanks;

[redacted]

9) Dry the tanks with hot air;

10) Purge the tanks with an inert gas;

11) Seal the tank;

12) Take the tank out of the pit and lower it to the dolly for return to the manufacturing area.

B. ENGINEERING SUPPORT FACILITIES

In any advanced design program, numerous engineering support facilities are required to efficiently expedite the engineering. A review has been made of the facilities required for the RIFT program. The existing facilities at Martin-Denver that are applicable to this program are discussed in this section.

A computer facility is available, including an IBM 7090, a Reeves analog computer, a Bendix G15 computer and an IBM 1620 computer.

Laboratories are available for dynamic, climatic, and acoustic testing. The acoustic testing facility has the greatest random noise acoustic capability of any in this country.

An aerodynamics laboratory is available for preparing wind tunnel models and for developing special instrumentation required for aerodynamic tests. A 40-ft-long shock tube capable of 20,000°R and shock velocities of 24,000 ft/sec (equal to Mach 22) is also available. The shock tube can simulate flight of 20,000 ft/sec, stagnation conditions up to 25,000 ft/sec, and altitudes up to 300,000 ft. It is also capable of full simulation of stagnation conditions for re-entry flight conditions over a range of 0 to 26,000 ft/sec and altitudes of 50,000 to 200,000 ft.

The instrumentation laboratory provides the capability of evaluating and developing measurement system components. The major equipment categories evaluated are transducers, signal conditioners, and telemeters. The facility for testing and developing the signal conditioners is a standard electronics laboratory containing precision audio oscillators, digital voltmeters, a Berkeley counter, a-c and d-c vacuum tube voltmeters, and Tektronic oscilloscopes. The facility provides for evaluating performance of telemetering equipment and systems. To determine the reliability and accuracy of FM/FM, PWM/FM/FM, and PAM/FM telemetry systems, the lab is equipped with a complete ground station.

A primary standards laboratory provides liaison between the National Bureau of Standards and the Denver Division in most phases of measurement activities. This laboratory provides a standards reference for pressure, vacuum, temperature, humidity, vibration, force, weight, light, energy, acoustics, a-c voltage, inductance, capacitance, magnetic flux, power, voltage, and resistance.

A central data recording (CDR) laboratory handles multiple data acquisition as well as data recording services. The facility is centrally located in the general purpose laboratory complex and provides data acquisition and recording for all test areas. Cable channels are available from the above test areas to CDR. Three types of channels are used, strain-gage channels to the analog-to-digital computer (Berkeley MINDS system), thermocouple channels to MINDS, and general-purpose channels.

The central data processing laboratory provides capability for the reduction of radio telemetry, test stand, and general engineering laboratory data. This facility will accept magnetic tape-recorded data and oscillographic data. An extensive amount of equipment such as digital systems, recorders, magnetic tape playback equipment, etc, is available for data reduction.

A metals laboratory evaluates the mechanical, physical, and metallurgical properties of metallic materials. Primarily, these evaluations are conducted on specimens obtained from a fabricated raw material or components rather than on a complete component. Three Baldwin test machines up to 150,000-lb capacity are available. Machines are also available for conducting fatigue tests, creep tests, combined tension compression, fatigue and creep, impact tests, and physical property testing.

The nonmetals laboratory provides capability for testing and evaluation of nonmetallic materials. Results obtained from these evaluations determine the proper usage of nonmetals in design and production. Test data may serve as the basis for material design criteria and for procurement specifications written by The Materials Engineering Department. In some cases when adequate commercial materials are not available, laboratory facilities are used in compounding and developing new materials. Tensile, flexural, compressive, impact, and fatigue strengths of structural plastics, thermoplastics, and elastomers can be determined using the equipment in the metals laboratory. The thermal conductivity of insulation materials can be determined from room temperature to 1400°F using an Alundum-guarded hot plate. Reflective tapes and other insulations can be developed using a vapor-deposition unit.

A hydraulic laboratory provides the capability for hydraulic component development and evaluation testing, and system development and evaluation under static and dynamic conditions.

The controls mockup laboratory is a control-system test facility designed to perform subsystem design confirmation tests, ground operational equipment (GOE) compatibility tests, component marriage tests, and trouble-shooting tests for problems encountered in the field. The test article consists of the complete airborne flight-control system including the hydraulic system and servo-actuators, which are mounted in the engine trusses, and representative missile skirt sections for each stage. The thrust chambers are represented by dynamically equivalent masses.

The electrical laboratory contains load banks, a power sequencing unit, a vacuum-corona test console, and a d-c motor generator for test and analysis of electrical subsystems.

The electronics laboratory is used for design and testing of units, subsystems, and systems of ground power-generation equipment and control circuits. The array of special purpose test equipment available for these tests include a-c and d-c power monitors, a power-supply analyzer, a line resistance simulator, a transient monitor set, and automatically sequenced ten-step a-c and d-c loads.

The inertial elements laboratory provides a vibration-free, dustproof, temperature-controlled area for designing and evaluating inertial elements and control system devices. To aid in this evaluation, four major test stations are used: a three-axis reference system, a rate gyro, a displacement gyro, and a completely automatic program test station.

The rf and antenna laboratory contains 2400 ft^2 of enclosed working area, 800 ft^2 of concrete surface, and 1200 ft^2 of roof area for free-space-type measurements. The enclosed area contains a model shop and spherical vacuum chamber. There are two complete antenna-pattern measuring ranges and an Antlab rotator for conducting pattern measurements.

The instrumentation laboratory contains three primary working areas for test and evaluation of transducers, signal conditioning and telemetry equipment. Environmental facilities are available for pressure, temperature, vibration, and acceleration tests. A special console is used for checkout and repair of signal conditioning modules. A complete ground station is used for evaluating the telemetering equipment.

The components testing laboratory contains four test consoles and environmental facilities for test and evaluation of all components not falling under the jurisdiction of the other laboratories. Test consoles used are semiconductor, amplifier, relay, and resistance-capacitance.

The electromagnetic interference laboratory certifies and qualifies all electronics, electrical, and electromechanical equipment by running conductive interference and susceptibility tests in compliance with military and Martin specifications.

The hydrogen research laboratory is capable of liquid hydrogen component and system development. Tests may be performed, under a variety of conditions the using liquid hydrogen, that simulate conditions encountered during preflight and flight operations. The hydrogen research laboratory is located in the hill test area of Martin-Denver near the main plant (Fig. V-1). It includes two test cells, a service cell, and a test support building for fabrication, instrumentation, test cell controls and a vacuum work area. The year-around test cells consist of a propulsion or airborne cell with a 60-in. flow system and a GSE test cell with a 1 1/4-in. flow system. Both cells are protected by heavy steel reinforced concrete walls on three sides. Control cables, instrumentation cables, and control tubing connect both test cells with the control room in the test support building.

Material properties testing is performed in a separate building. Two types of tests can be performed in this laboratory: measuring stress and strain of all kinds of material under very low temperature conditions, and obtaining heat transfer data through various materials at cryogenic temperatures. The liquid hydrogen storage area contains one vacuum-jacketed 13,000-gal. LH_2 storage tank, two mobile 1500-gal. LH_2 storage dewars, two mobile 1000-liter LH_2 storage dewars, and one mobile 600-gal. LH_2 storage dewar. Other test and support equipment includes stationary and portable vacuum pumps, leak detectors, instrumentation recorders, and fabrication and assembly equipment.

Present laboratory facilities and test equipment will be sufficient to test and evaluate almost all of the proposed RIFT systems and subsystems. Additional laboratory facilities that will be required to support the RIFT program are discussed below.

A two-cell vertical test facility (VTF) will be added to the present facility, using utilities and equipment available at that location. One cell will be a structural test cell where static tests will be performed on a complete structure. This facility will require fixtures and hydraulic jacks to apply external loads, additional quartz radiant heat lamps, and supporting fixtures. Existing instrumentation, data recording equipment, and liquid nitrogen storage facilities will be used.

This type of structural testing has been accomplished in cells E-1 and E-2 of the VTF for the Titan I program. The requirement for a new cell is dictated by the larger size of the RIFT tank.

The second cell will be for electromechanical testing. Again, the size of the tank dictates the need for a new cell. Electrical and electronic system compatibility testing using launch GOE will be accomplished in this cell. The GOE for the electrical airborne system and the operation of the airborne control relays will simulate countdown conditions. This type of testing has been accomplished for the Titan program at this area. Existing equipment and experience will be used to the maximum extent for the RIFT tests.

A static test facility will be added at the hydrogen research laboratory. This addition will be used to conduct the small-scale static test with liquid hydrogen. Liquid hydrogen will be provided from the 13,000-gal. LH_2 storage tank existing at the facility. For the liquid nitrogen test, the liquid nitrogen will be supplied by a truck-mounted dewar. The addition to the hydrogen research laboratory will be a 20x20-ft test cell with a concrete revetment.

Instrumentation and recording equipment currently located at this facility and at the nearby cold flow lab will be used for these tests to the maximum extent. Personnel from the VTF structural area will be responsible for conducting the tests.

Full-size LH_2 cold-flow testing of the RIFT tank will be accomplished at a new facility in the cell E area at Jackass Flats. This type of testing cannot be safely conducted at existing facilities in Denver. A new facility should be constructed at a site where maximum benefits can be derived by its location. The cell E area offers convenience to facilities that can be shared and shortens the supply line to LH_2 in California.

Radiation testing of materials, components, and electronic systems will be accomplished at established facilities such as the Los Alamos Godiva reactor; the Triga reactor at Arco, Idaho; the radiation effects reactor at Dawsonville, Georgia; the ground test reactor at Fort Worth; the Argonne gamma irradiation facility; or the cobalt 60 facility of The Martin Company Nuclear Division. Cell D and cell E at Jackass Flats, when in operation, will offer a newer and more representative radiation test facility. It will be very easy to mount test specimens in the reactor environment at that site.

The ground vibration survey tests will be performed in the Saturn dynamic stand at Marshall Space Flight Center in Huntsville, Alabama. This stand is capable of accepting the three-stage operational vehicle for dynamic testing. Mode shapes and frequency testing can be accomplished for free-free and cantilever conditions. All instrumentation data recording and data reduction equipment is located at that facility.

C. CAPTIVE TEST (JACKASS FLATS)

The RIFT captive test facilities are to be located in the Project 400 area of the AEC Nevada test site (Jackass Flats). Figure V-2 is a map showing existing, planned, and proposed facilities. Cells A and C are now being used for the Kiwi and ROVER nuclear engine test programs. Cell D, the RIFT nuclear engine development site, will be operational in 1962. Cell E, proposed for RIFT captive testing, is to be located about 2 mi west of cell D and will share many of the services and facilities at that site. Cells D and E, for example, will share the million-gallon water storage and demineralizing system for diffuser cooling.

Other 400-area facilities that can be used for the RIFT program include the powerhouse and substation, control building, technical services building, warehouse, office building, and administration building.

Major new construction required consists of an engine maintenance and disassembly (MAD) building, a storage and maintenance building for the airframe assembly, the captive firing complex (cell E), and interconnecting railroad spur and roads.

[redacted]

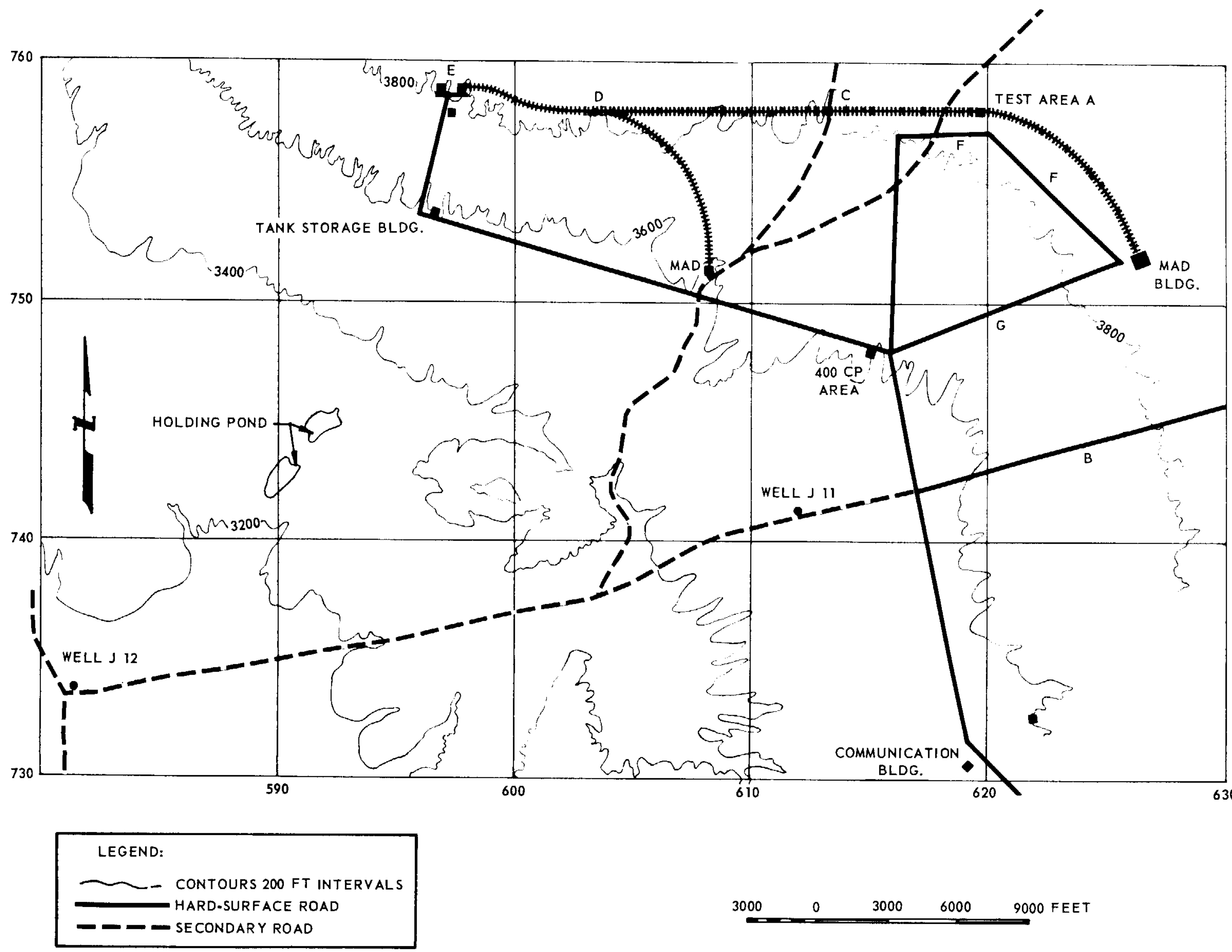

Fig. V-2 Nevada Project 400 Area

[redacted]

RIFT tanks are to be flown piggyback on a C-133 airplane from Lowry Air Force Base in Denver to Nellis Air Force Base near Jackass Flats. Transtainers (transport-containers) will be used for ground handling of the RIFT tanks from the Martin factory to Lowry and from Nellis to the 400 area (Fig. V-3). After testing at Jackass Flats, the tank will be flown to AMR for launching or back to Denver for rework.

1. Maintenance and Disassembly Building

A new MAD facility is required for RIFT engine and reactor-core assembly and disassembly. The design of this new facility is patterned after the existing MAD facility in the 400 area and used for the Kiwi nuclear-engine handling. The recommended MAD location is shown in Figure V-2. Cells D and E will share this new facility. A railroad spur connects the MAD building to cell E. The complete engine assembly is mounted on a flat car and positioned under the RIFT tank at cell E. The engine can be remotely connected or disconnected to the tank. Techniques and equipment developed at cell D are expected to be used to the maximum extent for this operation.

2. Storage and Maintenance Building

This 12,000-ft building will store up to three RIFT tanks and house specialty shops and office space for the RIFT program. Tanks will be delivered to this building from Nellis AFB. The RIFT tanks will be received and inspected in this building and transported by road to cell E. Aerodynamic fairings used during flight will be removed and stored there. A 24 kw standby diesel generator is also located at this building.

3. Captive Test Complex

The captive test complex shown in Figure V-4 consists of two test stands and the associated control center and propellant handling facilities.

a. Test Stand Structure

The test stand structure (Fig. V-5) consists of an aluminum tower superstructure to support the tank over a below-ground concrete engine-test pit and aluminum engine-exhaust diffuser.

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Fig. V-3 Air Transport of Tanks

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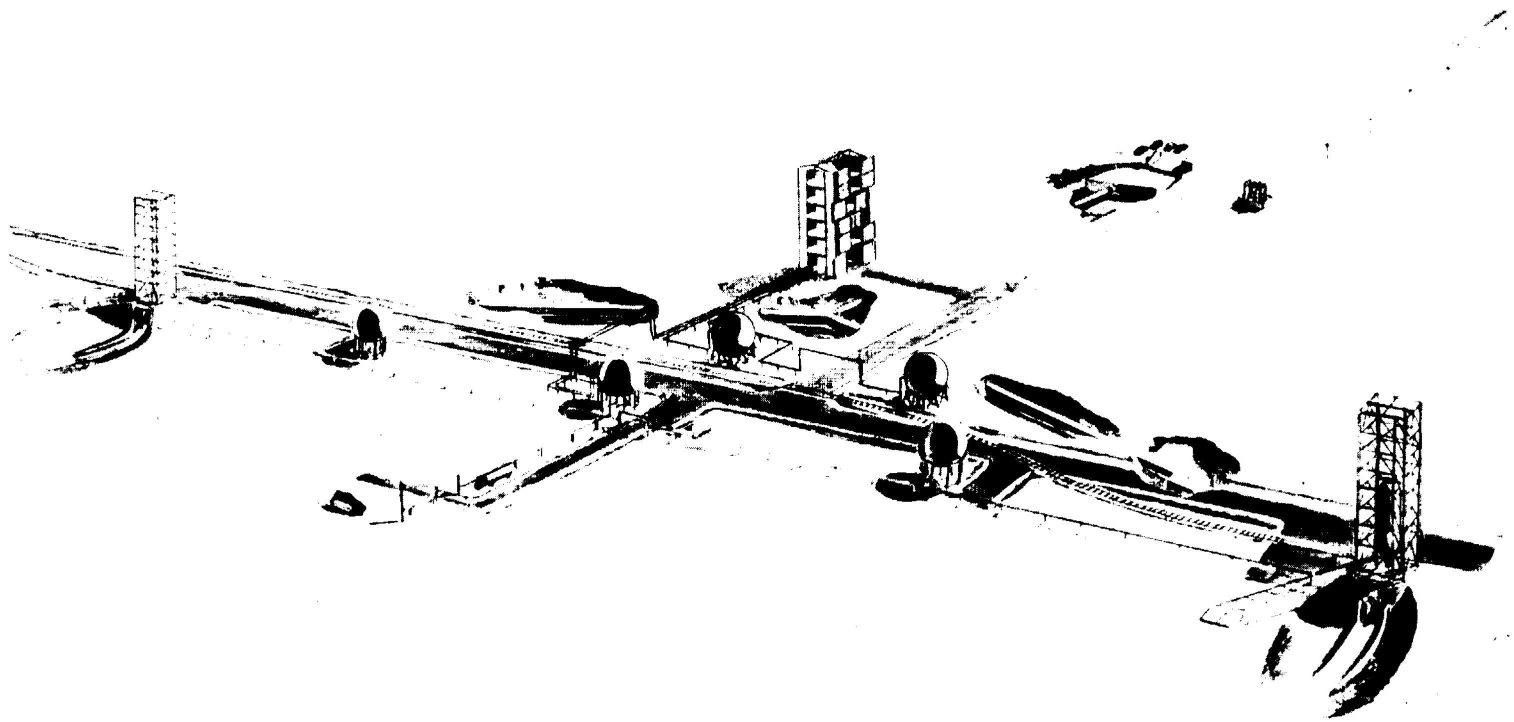

Fig. V-4 Captive Test Facility, Jackass Flats, Nevada

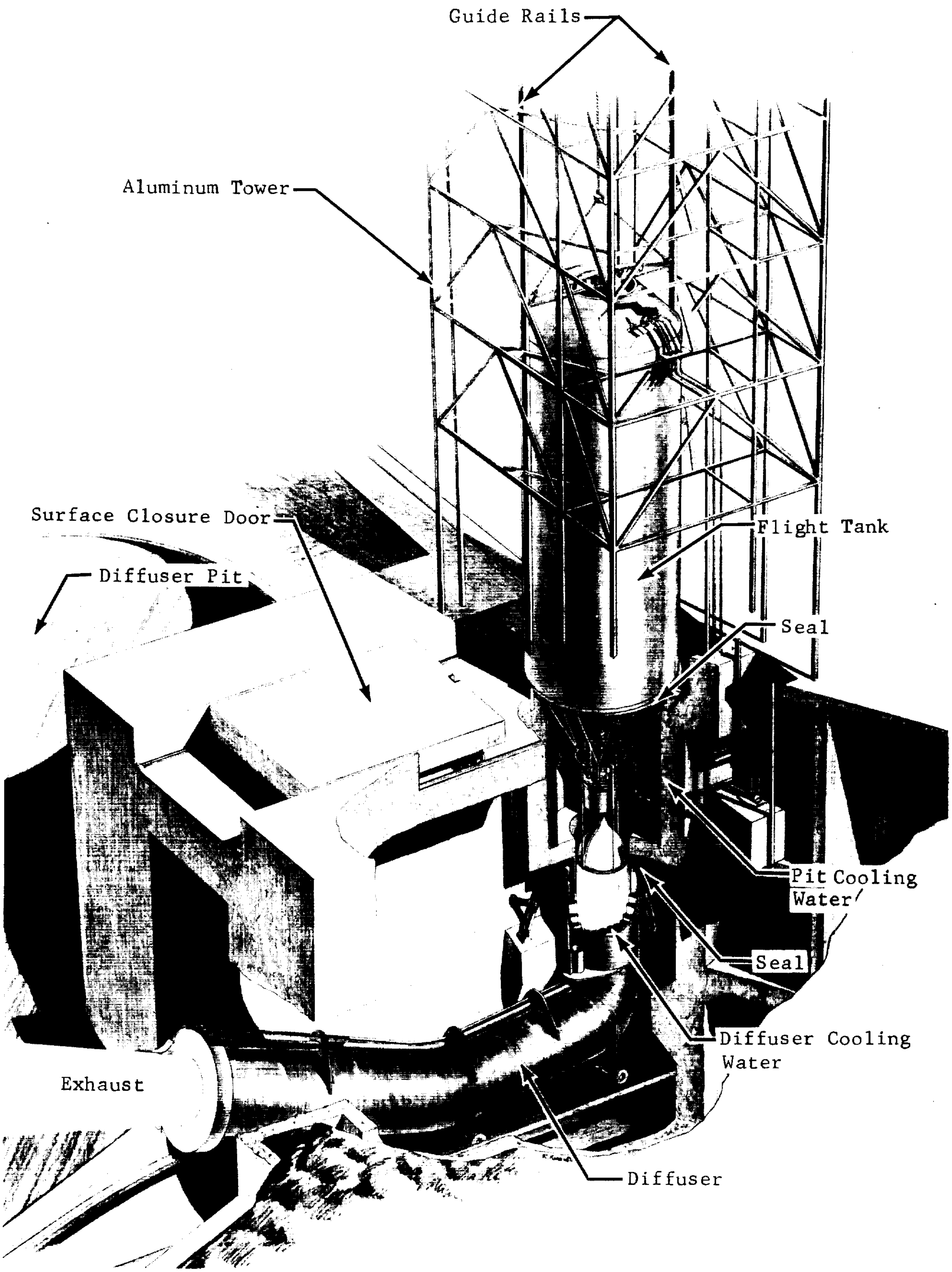

Fig. V-5 Captive Test Stand Structure

The aluminum superstructure accommodates missiles up to 140 ft long and 30 ft in diameter. The 2.3-min radioactive half-life of the aluminum (6061) structure permits test stand personnel to return to the stand within a day after a nuclear test.

The base of the superstructure is about 40x50 ft with an overall height of about 180 ft to accommodate the missile, stairs, elevator, work platforms, facility lines, and missile winch. Weather protection of test personnel and equipment is provided at work levels by canvass enclosures.

The reactor-engine test pit has 5-ft-thick concrete walls. Reinforcing steel is embedded near the outer face of the concrete walls away from the reactor to minimize reradiation from the steel to the test stand personnel after a hot firing.

Experimental data obtained from the Kiwi A-3 nuclear-engine test show that the concrete used at cell A is very radioactive after a nuclear test. A water-boron solution circulating in a tank surrounding the inside of the engine test pit of cell E absorbs a large percentage of the radiation from the nuclear engine. After a nuclear test, the same water-boron solution minimizes the reradiation from the concrete in the test area.

A 3-ft-thick concrete surface closure door absorbs radiation arising in the diffuser and test pit. This door is mounted on rails and is operated remotely.

Computations show that radiation absorption by the boron solution at the wall of the engine test pit and by the concrete door permits safe personnel access to the test stand 24 hr after a hot run engine is removed.

The engine-exhaust diffuser duct acts as an injector, providing a partial vacuum at the engine bell to simulate altitude operating conditions. Spaces surrounding the engine are purged with gaseous nitrogen to prevent explosive mixtures of air and LH_2 before and during engine startup.

The diffuser is 64 ft in overall length, with the last 25 ft deflected upward 20 deg from the horizontal to position the propellant exhaust above the ground. The LH_2 propellant-exhaust jet is ignited by a propane flare at the top of the diffuser duct where the propellant gas is mixed with air. The space between the inner and outer jacket contains demineralized cooling water. The inner tube has external fins at the elbow area where the greatest cooling is required.

The diffuser duct is mounted on rails. The rails are supported on the walls of the diffuser bay. A winch is used to roll the diffuser out of the diffuser bay into the exhaust pit to permit servicing or replacement.

The commodity lines and disconnects required for launch and static test firings are located along the skin of the missile on the pitch axis to conform with the Saturn umbilical tower and boom locations. For static test firings it is necessary to remotely connect or disconnect the umbilicals at the same time the missile is moved vertically. To accomplish this automatically, a ground adapter consisting of a downward-facing elbow and a slip-type disconnect, is bolted to each missile umbilical connection as shown in Figure V-5. These ground adapters are not required for flight. The vertical guide rails align the upper (male) half of the nuclear-stage umbilical connectors so that they engage the lower (female) half. Guides on the disconnects provide further alignment of the slip-type connectors during the engagement process.

b. Control Center

The concrete control center contains an operating area with recording room and a control room for each test stand, a maintenance and personnel control area, and a personnel control and protection area.

Interconnecting tunnels (shown in Fig. V-4) connect the two test stands with the control center. Air conditioning is provided for the control center buildings and tunnels.

c. Propellant Loading System

A cryogenic and gas storage facility has been sized to support one stand at a time. This facility includes the equipment necessary to store liquid hydrogen, liquid nitrogen, and gaseous nitrogen; transfer the cryogenic commodities; purge and fill the airborne tank; and top for the required time period. Remote operating valves are equipped with emergency controls for local operation and fail-safe features. Relief valves and safety lockout features are installed in the control systems.

4. Operation Procedure

Test stand operation begins with removal of the missile tank from the transtainer and lifting it into position on the test stand as shown in Figure V-6. The engine, positioned by locomotive, is raised and attached, using remote handling equipment. The surface closure door is opened by electric winch and the assembled tank and engine are lowered into test position (Fig. V-5). This is monitored by TV cameras and position-sensing switches located along the vertical guide rail track. The downward motion is stopped by the aft handling-ring seating against the upper lip of the engine test cell. A circumferential seal is self-energized by the differential pressure produced by the rejector operation of the discharge duct. The N_2 purges, cooldown, and LH_2 filling operations now proceed. Before the nuclear engine is started, the valves controlling the cooling water are opened to the diffuser duct and conduits at the walls of the engine test pit.

The flare on the diffuser duct ignites the escaping hydrogen gas to prevent an accumulation of gas in the stand area. After-cooling for the engine is provided by gaseous hydrogen. At the end of the after-cooling period, the missile and handling sequence is reversed. Test stand personnel can safely return to the stand one day after the engine test run.

5. Instrumentation

Evaluation of the captive-test phase of the instrumentation program indicates a need for presenting performance data with a high degree of accuracy on a real-time or near real-time basis. Identical techniques are desirable for both the captive and flight test configurations. Digital data techniques using an rf pulse-code modulation (PCM) link in conjunction with a buffer magnetic-tape unit and a small, on-line computer best satisfies the requirements. A parallel PCM radio link will be used for cross-checking system operation.

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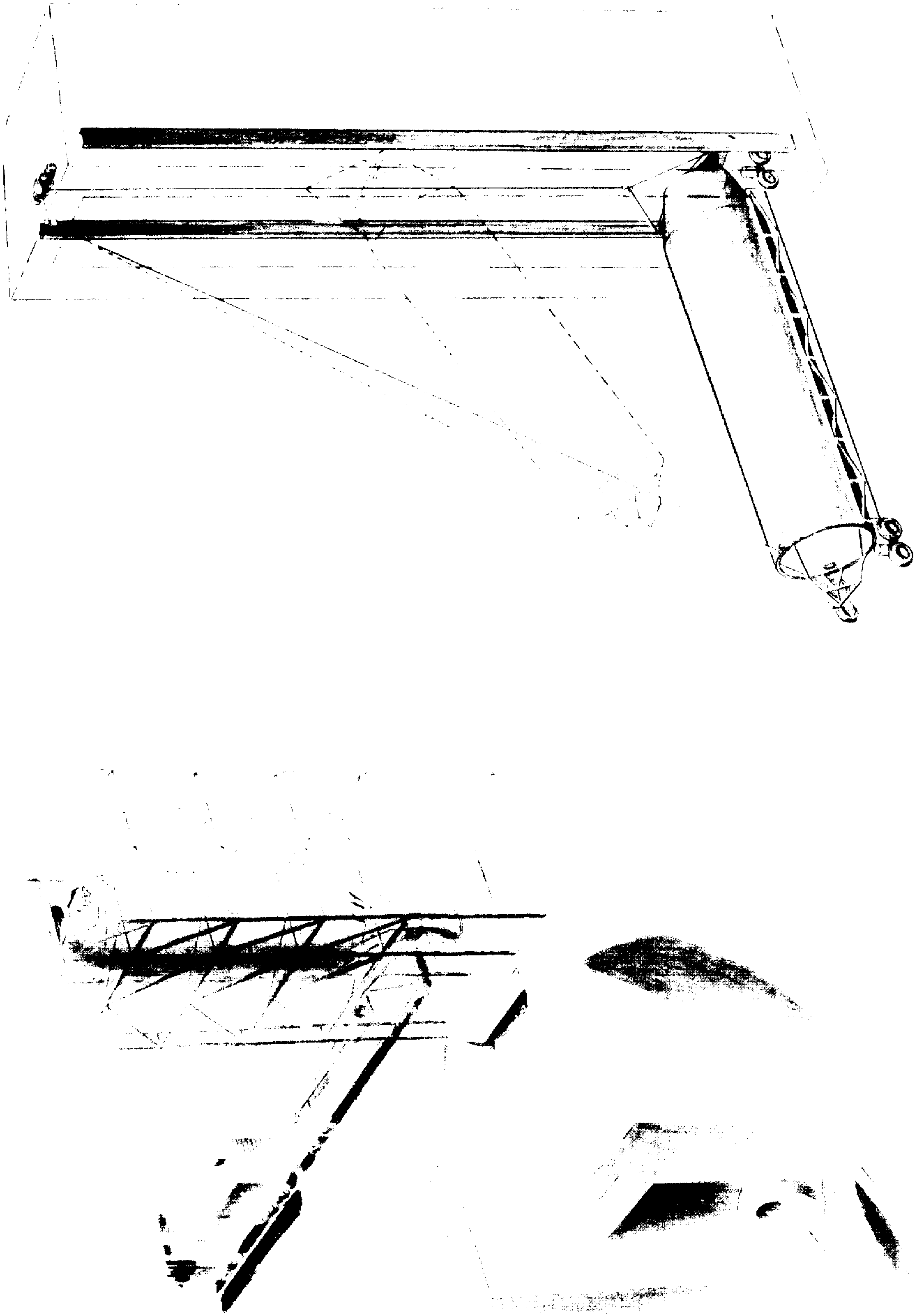

Fig. V-6 Test Stand Operation Procedure

The on-line computer will process the raw data into meaningful language for the design engineers; compare measured values with preprogramed values for scram, hold, or kills; and pass data to recorders for monitoring purposes. The data will be presented on x-y plots, recorders, electric typewriters, and/or punched paper tape and compatible teletype language.

Data from subsystem tests may be reduced in real time due to the relatively small number of inputs or parameters being measured. As systems are put together and tests become more complex, as in a complete missile static firing, all data will be recorded on a magnetic-tape buffer unit, and the computer will then operate slightly behind real time for all measurements except scram or kills. Scram, hold, and kill measurements can be programed so they appear on both telemetry sets for redundancy and reliability.

Five remote pads containing film cameras and television pick-ups will be strategically centered about the test stand to compensate for the lack of direct view of the article under test and to allow later documentation of the firing.

D. LAUNCH (AMR)

Each RIFT stage will be flown by C-133 airplane to the skid strip at AMR after completion of testing at Jackass Flats. The nuclear engine assembly, less core, will be stowed on a dolly inside the airplane, while the airframe assembly will be attached piggyback to the fuselage. Aerodynamic nose and tail fairings will be disassembled and used again.

At AMR the airframe assembly will be removed from the airplane and loaded on a transtainer by a mobile crane. This load will be hauled to an existing missile assembly building (MAB) for receiving and inspection. The engine will be moved on its dolly to a new facility, the nuclear engine assembly and checkout building (NEAC).

After the engine is completely reassembled (including a new core) in the NEAC, it is moved on its dolly to the MAB for mating to the airframe assembly. The transition structure is then added around the engine and the complete stage on its transtainer is hauled to Saturn Complex 34, or 37. The RIFT stage is erected by the Saturn gantry crane. The addition of a nose cone completes the flight configuration. Figure V-7 illustrates the complete missile configuration at Complex 34. Figure V-8 shows the complete complex and Figure V-9 illustrates the action at liftoff.

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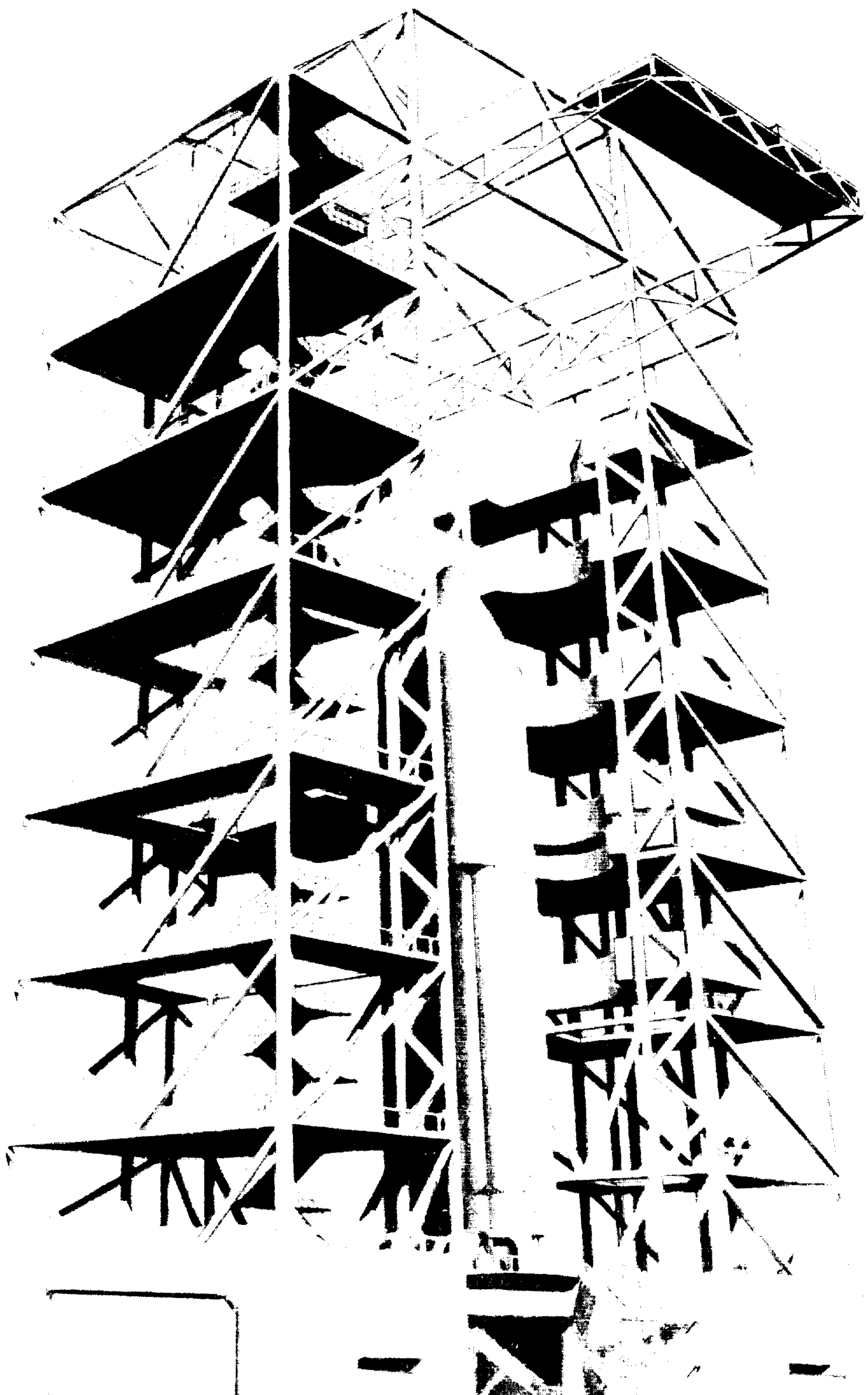

Fig. V-7 Saturn-RIFT Service Gantry

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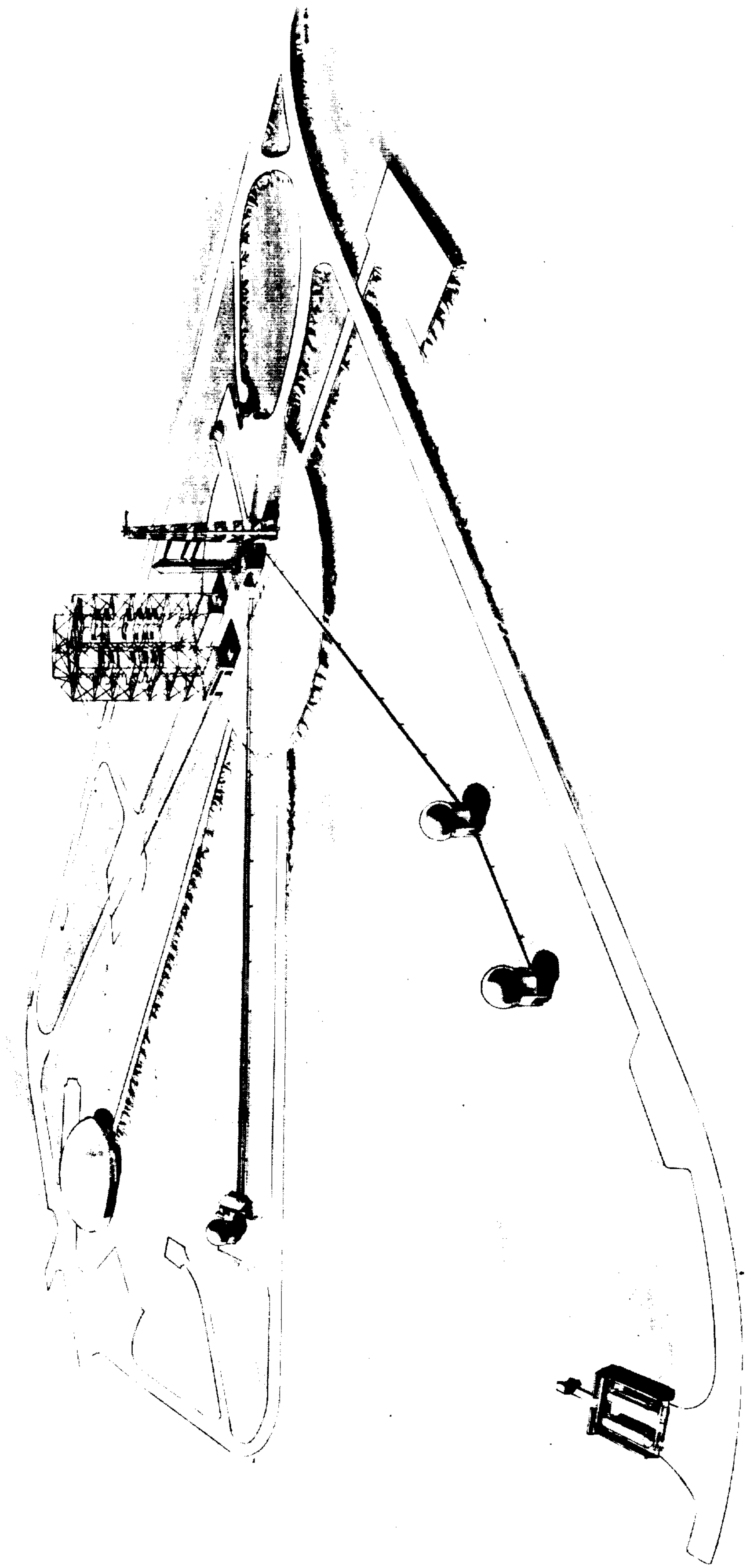

Fig. V-8 Saturn Complex

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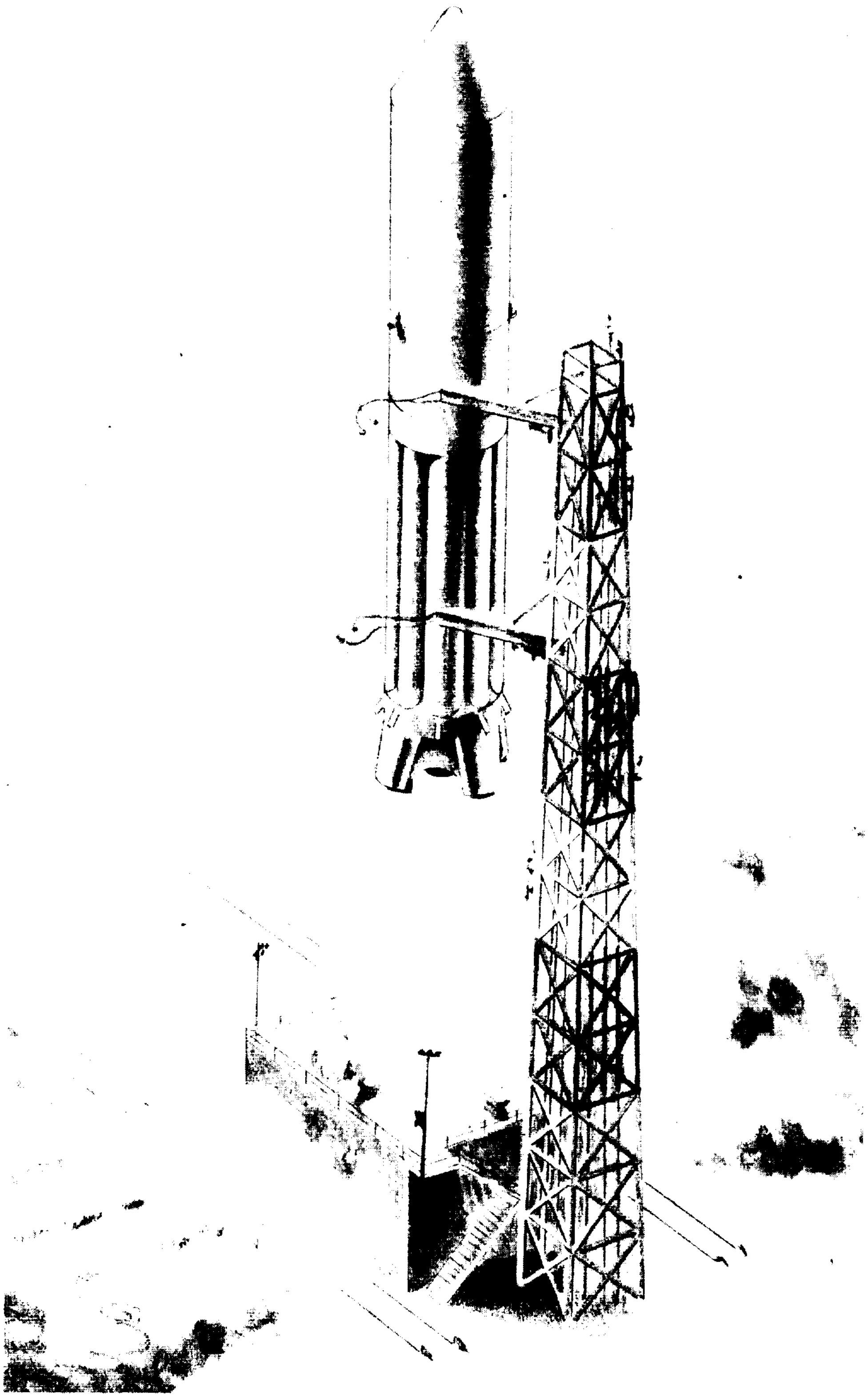

Fig. V-9 Action at Liftoff

[redacted]

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1. MAB Facility

Existing hangers, such as Titan hangers N or U, will be used at this facility. Thirty-foot-high bays and ample floor space make these hangers ideally suitable. Existing shops, laboratories, and office space can be made available. Bridge cranes of 25-ton capacity are now installed.

The primary function of the MAB is to receive, inspect, assemble, disassemble, maintain, and service the complete stage and its subsystems. A minor amount of checkout, pressure testing, and functional testing occurs.

The specialty shops include machine shop, sheet metal, instrument room, welding, carpentry, tool room, electronic repair and chemical cleaning. The laboratories now in use include chemical analysis, hydrostatic and pneumatic, environmental and electronic calibration, plus associated technical files and inventory control facilities. Complete system checkout consoles will be provided on the assembly floor.

2. Nuclear Engine Assembly and Checkout (NEAC)

Nuclear engine testing at low power levels reveals whether the reactor has been properly fueled and assembled and is mechanically operative after transportation to AMR.

The NEAC building (Fig. V-10) is structurally divided into reactor and engine cells, control room, laboratory, fuel storage, work area, and standby diesel-generator room.

The outside walls of the cell and the sliding equipment door are 5-ft thick concrete. This construction limits the maximum exposure at the perimeter of the 500-ft radius exclusion area to approximately 3.5 rem for a nuclear excursion whose energy release is equivalent to the total release from a full-power run of 300 sec. The control room and maze entrance walls are of 6-ft thick concrete limiting the maximum total dose to operating personnel at approximately 7.5 rem from a limited nuclear excursion. A steel personnel door at the maze entrance will provide sufficient protection from scattering effects. Under normal reactor operating conditions, there will be merely background radiation outside the reactor cell.

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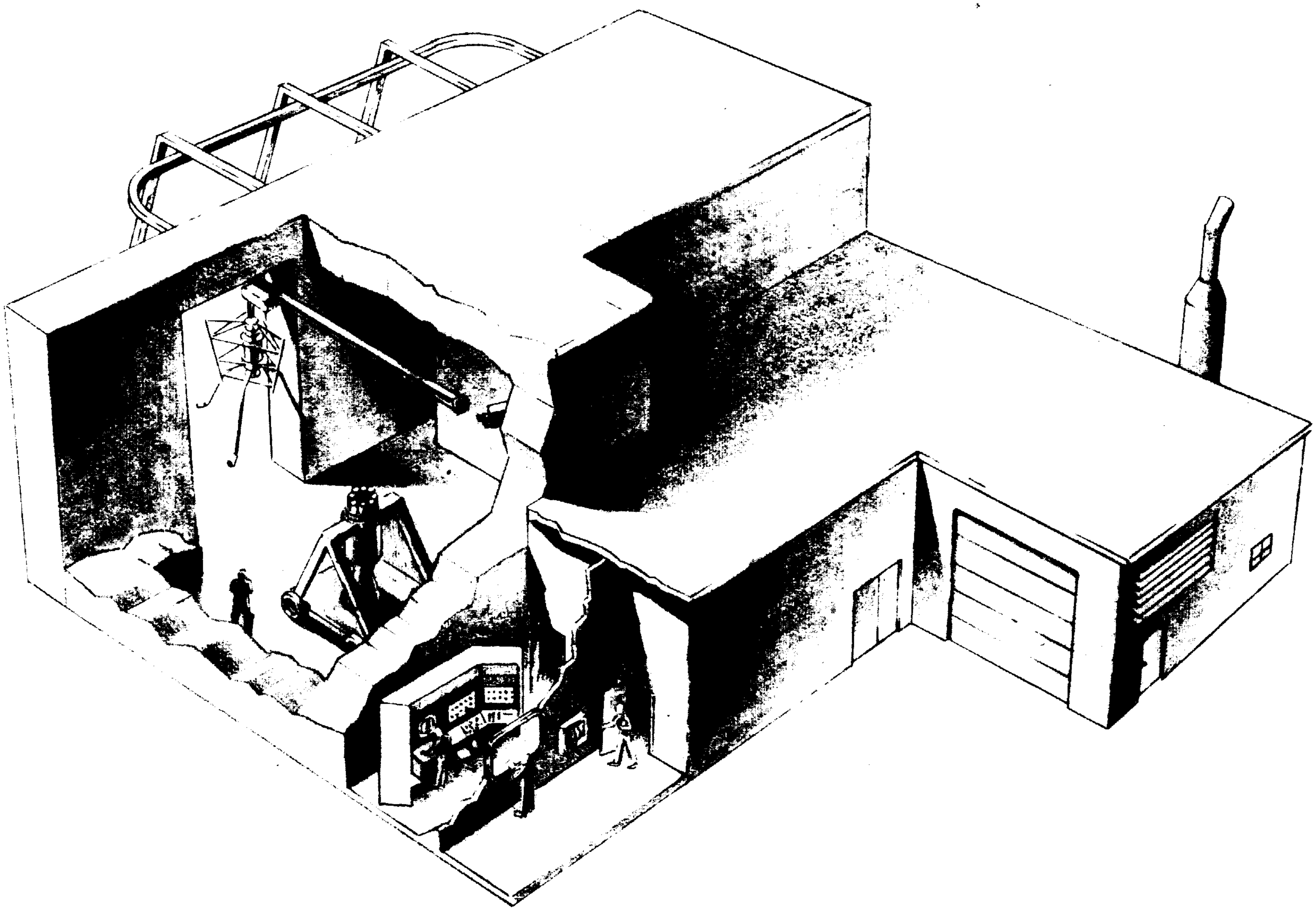

Fig. V-10 Saturn-RIFT Nuclear Engine Assembly and Checkout

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Handling equipment in the reactor cell consists of an overhead monorail crane and a reactor dolly. The cell contains wells for storage of reactor rods and the instrument calibration source. The engine cell shares the overhead monorail with the reactor cell crane. The cell contains a test stand and engine dollies capable of handling the engine assembly in the vertical attitude.

The air conditioning, heating, and ventilation systems prohibit an air flow interchange between the reactor cell and the rest of the facility by maintaining a slight negative pressure in the cell. Incoming air to the reactor cell passes through glass wool filters and is power-exhausted through absolute filters. The humidity in the cell is kept at a constant level so environmental factors are the same for each test. Fume hood-exhaust fan-filter units are provided in the work area.

The control room contains the instrumentation necessary to monitor and control the mechanical and low-power nuclear reactor testing. A TV monitor in the control room provides visual surveillance of the core tests.

The laboratory area contains a counting room and a dark room for facility support.

The engine core inventory and spare fuel elements are safely accommodated by the fuel-storage area. The elements are stored in special racks, and work boxes are so arranged that criticality cannot be attained even if the vault becomes flooded with water. Protection is also provided to guard against fire and blast.

The work area contains space for hand tools and light machine tools for making minor repairs and alterations to the assemblies. It also houses spare parts, experimental materials, portable health-physics monitoring equipment, and an instrument maintenance area.

Pumps are provided for collecting and monitoring liquid wastes from the work area. If the waste radiation level permits, the effluent will be discharged into the conventional waste system. If the radiation level is above an acceptable limit, the effluent will be pumped into 55-gal. drums for disposal by the health physics unit.

A 24-KW diesel generator provides emergency power to critical instrumentation and control circuits.

The main sequential functions performed at the NEAC are:

1) Receive and inspect the nuclear engine assembly;

2) Receive fuel elements at the reactor cell;

3) Assemble the reactor and perform mechanical check of the control mechanisms;

4) Perform a criticality check on the reactor to ensure that each core is compatible with the others by reference to position of control drums. This test is run without the use of a hydrogen coolant-moderator;

5) Run a low-power test and map the core as a supplemental check on the loading configuration;

6) Mate the engine to the reactor in the reactor cell. Remote handling is not required;

7) Run another low-power test;

8) Transport the engine package to the MAB for mating.

3. Modifications to AMR Saturn Facilities

Modifications to Saturn facilities to accommodate the nuclear stage consists primarily of repositioning work platforms on the gantry (Fig. V-7), providing space in the control center for consoles and supporting racks, providing nuclear alarm equipment, providing two umbilical tower booms at the proper elevations, and providing routing and support for control and umbilical lines.

Two umbilical booms extend from the Saturn umbilical tower to within 5 ft of the skin of the nuclear stage. Draping the umbilical lines allows relative movement between the missile and tower. At liftoff, the disconnects unlatch pneumatically and the umbilical booms rotate out of the path of the missile drift cone, (Fig. V-9). This umbilical boom operation is compatible with the Saturn S-I operation.

A 6-in. diameter vacuum-jacketed LH_2 fill, and a 4-in. air conditioning connection are required in the nuclear stage engine compartment. Three umbilical connections are required in the guidance compartment; 10-in. diameter tank vent, 8-in. diameter air conditioning, and 6-in. diameter electrical. The 6-in. LH_2 fill and the 10-in. tank vent are both double-walled vacuum jacketed to minimize freezing, and have spherical seats for relative motion between umbilical booms and the stage.

The two 125,000-gal. LH_2 storage dewars at Complex 34 provide sufficient liquid to fill the R&D nuclear stage and leave a 60% reserve. Three 125,000-gal. LH_2 dewars planned for Complex 37 will provide sufficient liquid to fill the operational stage and leave a 60% reserve. The dewars will have an operating pressure of 40 psig.

A 20,000-gal. LN_2 dewar has been added to meet the checkout, purge, cooldown, and nitrogen-operated valve requirements of the RIFT nuclear stage.

Minor modifications and additions to GOE/GIE are required at the Saturn launch complex. The instrumentation used at Jackass Flats will be applicable at AMR.

VI. TEST PLAN SUMMARY

RIFT test planning must be organized to focus test objectives to the program objective of achieving successful third-stage flight to escape velocities. Test plans should be developed to demonstrate the performance specifications for systems, subsystems, and components. These plans should be identified with each testing activity.

Test plan tree development should be rigorously integrated with the progressive development of specifications for the acceptable performance of the RIFT vehicle. Early initiation of test planning, concurrent with the design phase, will minimize duplicate and dead-end testing and expense. This approach will in turn result in the definition of only the primary and necessary flight test objectives.

This chapter describes the test phases of the RIFT program with emphasis on systems test plans. Subsystem testing, which is summarized here, is more fully described in Volume III. A test summary table is given in Table VI-1.

A. FLIGHT TESTS

The flight test program, as a step toward providing a deep space penetration vehicle with the specification payload, must achieve two primary goals. The first is the demonstration of a destruct system that will prevent any possibility of an incident that would be injurious to the best interests of the U.S. The other goal is to demonstrate that the reactor-powered stage with the booster will function satisfactorily as a system in flight.

The program, to achieve these goals, is accomplished in three steps:

1) Lob flights, primarily demonstrating a chemical destruct system;

2) Suborbital flights demonstrating a passive destruct system;

3) Escape flights demonstrating the complete system with specification payload.

Table VI-1. RIFT Program Summary

Test Phase	Purpose	RIFT Articles	Test Site
A. System Tests			
1. Flight			
Lab (3)	a) Prove altitude start, mechanical and chemical destruct system, range safety, and fallout net	a) 3 RIFT L	AMR
Suborbital (3)	b) At orbital speeds, demonstrate passive (aeroheating) destruct and engine operation	b) 3 RIFT O	
Escape (3)	c) Operational capability (deliver 46,500-lb payload into deep space)	c) 3 RIFT E G for stand activation	
2. Flight Certification (Flight Vehicles)	Quality flight vehicles for flight test	All RIFT flight vehicles	Nevada Nuclear Test Site
3. Captive	a) Marriage and compatibility of engine and vehicle	G vehicle for stand activation, 2 RIFT A vehicles, 1 RIFT A_L vehicle	Nevada Nuclear Test Site
	b) Compatibility of operating and support equipment, crew, and operating procedures with RIFT		
	c) Launch crew training		
4. Manufacturing	a) Receiving/post-indication functional verification	All A, L, O, E, and G vehicles	Denver: hydrostatic test fixture, X-ray lab, and fabrication facility
	b) Assembly performance verification		
	c) Production and customer acceptance		
5. Vehicle Laboratory Test	a) Prototype assembly compliance with electrical-mechanical specifications	G vehicle	Denver: new vertical test cell
	b) Ground operating equipment and vehicle operational compatibility		
	c) Develop test and acceptance procedures		
B. Component and Subsystem Tests			
1. Electrical-Mechanical	a) Development and evaluation		Denver: GPL VTF
Components	b) Compliance to specifications		
Subsystems	c) Qualification		
2. Radiation			
Neutron and Gamma	a) Extent of radiation on nose cone components		Los Alamos: Godiva Reactor Argonne: Gamma Radiation Facility
Engine Firings	b) Qualification of components/subsystems to firing environment	Captive vehicles (for captive tests)	Idaho Falls: MTR Facility Nevada Nuclear Test Site: Captive
3. Engine and Engine Destruct System	(Not included in report - engine development accomplished by engine manufacturer)		
4. Wind Tunnel	a) Establish aerodynamic force and pressure distribution and nonlinear coefficients	<u>Partial Scale</u>: Saturn S-I/RIFT Saturn S-I, S-II/RIFT	NASA: Langley, Ames Lewis Labs Denver Cold Jet: staging
	b) Investigate wind-induced oscillation, staging, and panel flutter		
5. Structural and Dynamic			
Component	a) Development and specification compliance	S and S_L vehicles	a) Denver: general purpose lab, hydrogen research lab, and new vertical test cell
Static	b) Complete structural performance in simulated operational environment		b) Denver: new vertical test cell
Dynamic	c) Dynamics of vehicle in simulated operating environment		c) Huntsville: Marshall Space Flight Center
6. Propellant Feed System			
Components/Subsystems	a) Early development; subsystem evaluation		a) Denver: hydrogen lab
System	b) Cold flow functional performance	Cold flow - 2 C, 1 C_L, and 2 H vehicles	b) Nevada Test Site: full-scale vehicle tests

Each flight step is described in the following paragraphs.

1. Lob Flights

a. Goals

The lob flight program is a limited range test with limited propellants to assure that no possibility exists of the vehicle exceeding the boundaries of the control range. Whenever the nuclear engine is ignited, the flight path and any predicted impact area will be over deep water. Thus, a failure of the destruct system will result only in the engine being deposited in deep water in the radioactive condition. This is acceptable to the AEC.

Over shallow water the mechanical destruct system will be used to destroy the geometry of the reactor. The proper functioning of this system of destruction can be conclusively demonstrated on the ground so that its operation in flight can be satisfactorily predicted. An undesirable nuclear incident could occur if the reactor impacts in shallow water or on land within the AMR range. Therefore, the additional protection of the mechanical destruct system is added to disperse the fuel elements, preventing even the shallow water impact incident.

The flight plan will include normal operation of the Saturn I booster and a short duration (approximately 200 sec) run of the 54,500-lb thrust nuclear engine. At the end of the flight, engine shutdown will be initiated by actuating the chemical destruct system, which is described in Volume III.

b. Configuration

The configuration will be as follows:

1) Saturn I first stage;

2) RIFT engine, 54,500-lb thrust;

3) Tank destruct system of both the S-I booster and the liquid hydrogen tank of the RIFT stage;

4) Ballast in the nuclear stage (for weight, speed, and shutdown control when partial load of liquid propellant is used).

c. Criteria for Success

The lob flight program will be successful if:

1) Airborne and external measurements show conclusively that 100% of the reactor was consumed or dispersed sufficiently for satisfactorily low radiation levels. (The chemical destruct system will function at a high enough altitude so that the consumption processes will be completed prior to impact. Thus the chemical destruct system may have to function in the presence of aerodynamic heating);

2) The nuclear booster engine starts satisfactorily, develops rated thrust, and runs stably for a long enough period to assure steady-state operation. However, it is not intended to permit the engine to run longer than 200 sec.

2. Suborbital Flights

a. Goals

The primary goal of the suborbital flights is to demonstrate the operation of the engine and the destruct systems at orbital speeds, while keeping the vehicle in a controlled range. The nuclear vehicle will be boosted to the same staging speed as in the lob flights, but will have a trajectory so that at the end of the nuclear engine operation the speeds in an attitude-down powered flight will approximate those of orbital flight. This flight technique will permit testing of the passive aerodynamic destruct system under controlled conditions, in complete safety, since impact and engine operation will be over deep water.

The second goal is to run the engine for its full duration of 900 sec. This will demonstrate engine function to propellant exhaustion and provide combined aerodynamic heating and nuclear heating environments to the propellants.

With the completion of the suborbital flight trajectory, the complete RIFT mission will have been demonstrated to complete the flight prerequisites for a deep space shot in the next and last phase of the RIFT program.

b. Configuration

The configuration will be the same as the lob flights except that the full propellant load ballast, as used in the nuclear stage for lob flights, will be eliminated and replaced by a full liquid hydrogen load.

c. Criteria for Success

The criteria for success of the passive aerodynamic destruct system will be the same as in the lob flights; namely, radiation and dispersion must be at levels acceptable to the AEC.

The mechanical destruct system will be demonstrated in these tests, since the function of the passive aerodynamic destruct system depends on dispersing engine pieces so aerodynamic heating will consume them.

3. Escape Flights

a. Goals

The primary goals of the escape series of flights is to deliver the 46,500-lb payload into deep space. To do this, it will be necessary to use the Saturn S-I, S-II booster. This will be the first time that this is undertaken with the nuclear stage. Therefore, this phase of the RIFT program represents a complete system test and the culmination of the program. The destruct system that proved most reliable and satisfactory from the preceding lob and sub-orbital tests will be used as the permanent destruct system for the escape flights. Thus it is seen that the RIFT program has planned the ability to select one of two alternate destruct systems. This approach seems well advised in view of the design difficulties that may be expected in a development of this type.

b. Configuration

The configuration will be the Saturn S-I, S-II booster plus the 80,900-lb thrust nuclear stage with a destruct system to be selected.

c. Criteria for Success

With the accomplishment of the escape mission, the RIFT program will have achieved the goals established.

B. FLIGHT CERTIFICATION FIRINGS

Flight certification firings are solely for achieving a high degree of confidence in test vehicle operation prior to delivery to AMR. Little or no engineering parameter studies are planned for captive tests. During the Titan development program when many changes in configuration were introduced, much of the flight success of the Titan was attributed to this test phase.

1. Goals

The goals of the flight certification firings are to:

1) Conduct a successful vehicle checkout using the ground operating equipment, procedures, and typical crews for flight tests;

2) Conduct a short-duration firing.

2. Configuration

The configurations used in these firings are:

1) The test article intended for flight;

2) Primary instrumentation measurements will be those planned for flight. Measurement requirements will be less than those required for parametric investigations of the captive tests. The measurements recorded must be adequate to completely determine trouble that can be reasonably expected in flight.

   Saturn booster stages are not required for the flight certification firings. Certain ordnance items and possibly range safety items such as beacons and Azusa gear may be omitted.

3. Criterion for Success

The criterion for success will be satisfactory operation of the vehicle so that it can be reasonably expected to complete its flight program.

C. CAPTIVE TESTS

Captive tests are the first functional tests of the complete vehicle. During captive tests, system design parameters are measured to evaluate the performance of the complete nuclear flight article. This step in the test program is emphasized because the RIFT stage will be captive tested at the Nevada Test Site, not AMR. The data acquired during the captive firing program will be most valuable in preparing flight vehicles for flight tests. Detailed analysis of subsystems performance is not planned for captive tests since this information will be acquired at other test locations provided by the subsystem contractors.

1. Goals

The primary goals of the captive tests are as follows:

1) Determine compliance of subsystems to interface specification;

2) Assure that all of the ground operating equipment functions satisfactorily, and demonstrate that this equipment will check out the nuclear stage for a flight. Flight crew test procedures will be generated before and during the captive tests. (Flight crews will be trained for operations at AMR);

3) Demonstrate that the nuclear stage can operate for the full duration;

4) Measure the environments created by the nuclear engine and compare with the design criteria and appropriate subsystem interface specifications;

5) Demonstrate the proper functioning of the circuits and components that initiate the engine destruct system. (Engine destruction is not planned for the captive firing test program).

2. Criteria for Success

The criteria for success of the captive test program are:

1) Acquisition of sufficient engineering data to determine whether system performance (flight parameters) is within specification;

2) Compliance with design criteria or sufficient information to enable a change to be made in the criteria and interface specifications;

3) A satisfactory demonstration that the crews, procedures and GOE can reliably check out the RIFT stages repeatedly for the flight test program.

3. Configuration

The configurations for the captive test program are:

1) The nuclear stage will consist of a small tank and 54,500-lb thrust nuclear engine for tests relating to the lob firing program. These tests will be short-duration firings;

2) The large tank with an 80,900-lb thrust engine will be used for the tests relating to the suborbital shots and the escape shots;

3) There will be no captive test program conducted on the Saturn S-I or S-II, since they will be completely checked at Huntsville and attached at AMR at the time of assembly for flight.

During the test program a dimensional-fit version of the nuclear stage should be sent to Huntsville for initial assembly on Saturn. A complete flight controls and guidance system and all other program circuitry should be included in this dimensional-fit vehicle, to check circuit interfaces prior to the first mating of the nuclear stage and the Saturn at AMR. A dummy engine would be the extent of the propulsion components that would be in the dimensional-fit vehicle.

[redacted]

D. MANUFACTURING TESTS

The Martin Company has established an extensive technique for ensuring high quality vendor- and Martin-produced components. This system involves comprehensive inspection and production environmental testing when the components are received and before they are incorporated into the missile assemblies. These missile and ground operating equipment assemblies, called control points, are systematically inspected and tested to the requirements of engineering specifications. The procuring agency's quality control personnel review the inspection and sell-off method, and witness all important tests, particularly where an article is a deliverable piece of equipment.

E. VEHICLE LABORATORY TEST

Confirmation testing of the complete electromechanical assembly with a non-nuclear, electrically functioned engine will be accomplished on the first complete vehicle (G) to be produced. The vehicle will be placed in the new vertical test cell and all systems will be actuated separately, and then according to the flight sequence by the ground operating equipment. In addition to confirming compliance of subsystems and systems with design specifications and checkout of operating procedures, the vehicle will be used to develop acceptance test procedures applicable to captive- and flight-test articles.

[redacted]

F. SUBSYSTEM TESTS

For engineering design confirmation purposes, subsystem test programs will be undertaken at each contractor facility. These programs will demonstrate that the subsystems will perform within the design criteria environment to the performance and interface requirements. Thus a test plan tree is generated, which will represent all of the demonstrations for the integrated specification tree for the entire RIFT operational system. A summary of the contemplated subsystem tests follows. Full treatment of these tests appears in Volume III.

1. Electromechanical Tests

Before subsystems are assembled for engineering tests, each component involved will be thoroughly tested and evaluated to ascertain its compliance with engineering specifications. Special consideration will be given to tests of the following;

1) Guidance system;

2) Flight control system;

3) Electric power distribution system;

4) Range safety position determination and command destruct link system.

2. Destruct System Test

The agency providing the nuclear engine will be responsible for the development testing of the engine destruct system. These tests should be undertaken concurrently with the development of the engine and would be generally in the nature of an additional design criterion for the engine. Not all of the three destruct systems can be completely tested on the ground prior to the flight program. The mechanical destruction of the geometry of the reactor can be clearly demonstrated, and information as to the dispersion and the size of the pieces will be made available. The chemical destruction of the engine can probably be done to some degree at the nuclear test facility, but may well present some problems due to the dispersion of the products of deterioration of the engine. The passive aerodynamic method of destruction may be only demonstratable in a small-scale wind-tunnel program.

3. Propellant Flow Test

The liquid-hydrogen propellant-feed system will be cold flow tested at the Nevada Test Site for design confirmation of tank outlets, slosh baffles, and associated propellant system components such as valves, regulators, and pressurization equipment.

4. Structural Tests

The structure of the RIFT stage will be subjected to a series of static tests and dynamic tests, such as vibration of the complete structure. Where special structural techniques are used or unusual engineering problems exist, structural components will be subjected to additional test. Information as to the elastic characteristics of the structure will be required, both experimentally and from calculations, to enable reliable predictions of the vibration modes when connected to the Saturn stages.

5. Wind Tunnel Tests

Wind tunnel tests will be performed to firmly establish parameters of nonlinear aerodynamic coefficients, pressure distributions, panel flutter criteria, boundary layer profiles, wind-induced oscillation effects, and fire-in-the-hole staging for each RIFT/ Saturn configuration.

6. Radiation Tests

As necessary, all components and materials will be tested in the radiation environment. It is expected that electronic system components will require the most attention, and many materials will require qualification for use in the radiation environment created by the engine.

[redacted]

VII. PROGRAM SCHEDULE

The complete development program consists of three primary efforts. The first effort, already underway, is the development of a large chemical booster system required for the flight-test program and for which the operational nuclear vehicle would serve as the third stage. The second·effort involves the design, fabrication, and test of a nuclear propulsion system for this upper stage vehicle. The third effort is the design, fabrication, and ground and flight testing of the complete powered upper stage system.

A. GENERAL PROGRAM PHILOSOPHY

The development plan emphasizes the design, fabrication, ground and flight testing, and support of the upper stage vehicle system. The program summary (Table VII-1 and Fig. VII-2) refers to the anticipated corollary development of a nuclear engine and the primary boost vehicle.

To assure effective, adequate, and timely development of the upper stage flight system, the plan and program for vehicle development and ground testing are under the direction of the airframe manufacturer as integrating contractor. The flight-test program is under the cognizance of the primary booster program management.

Programing of this development effort is based upon engineering and fabrication techniques proved on Titan and other programs. The experience derived from current programs in the areas of development and confirmation testing will also be applied. Significantly affecting this effort were the considerations given to hazards expected in the ground and flight testing of a nuclear power source. The experience and data available from the Atomic Energy Commission and other organizations conducting work with nuclear power sources, such as Martin's Nuclear Division, have been used in planning, timing, and phasing this program.

[redacted]

Overall development time for this vehicle is minimized by concurrently programing the development of the engine and the flight vehicle system. Close coordination and timely interchange of design criteria between the engine, airframe, and primary booster manufacturers will provide a well sequenced program. Engine interface data, primary booster and payload interface data, and projected flight dynamics and loadings furnish the basis for structural design, which is confirmed in static and dynamic structural testing. Captive ground firings and flight tests confirm the combined system design. The flight-test program progresses from ballistic lob shots that confirm the air start capabilities of the propulsion system and the reactor safety systems to escape flights intended to exercise the system for the full range of operational capabilities.

The development plan also includes programing to attain the capability to support the development effort and to provide the facilities required for fabrication and test of the vehicle.

The program summary portrays the above-described development effort graphically in Table VII-1 and Figure VII-1.

B. DEVELOPMENT OF THE PROGRAM SCHEDULE

Because of the hazards associated with ground testing and launching a nuclear-powered vehicle, flight testing of this vehicle must be accomplished by an air launch and air start of the nuclear engine at an altitude where radioactive debris present a negligible hazard. This condition establishes the need for a flight-test booster. Although an interim booster, for example Titan II, could be used for the early flight test, more effective programing would result if the flight-test booster were of a configuration more compatible with the larger booster to be used in operational programs. Saturn was selected from the large booster possibilities because it is the furthest developed and it could be used as the primary boost system for programs involving the nuclear vehicle. Two target dates were established in the development program, based on available information concerning Saturn booster development. The first date was mid-1965 for the start of flight testing, using an operational Saturn S-I stage as the primary booster and the nuclear vehicle as the second stage. The second date set was early 1967 to flight-test the nuclear vehicle as a third stage in this booster system, using the operational Saturn S-I and S-II stages for primary boost.

Table VII-1. RIFT Program Schedule Summary

Line and Page		Major Program Element/Milestone	Start	Complete	Span in Months
5	1	Program Go-Ahead, Anticipated and Firm	7-61	10-61	3
42	1	Fabrication Facility	7-61	1-63	18
45	1	Propellant Flow Facility	7-61	8-63	25
6	1	Preliminary Design	10-61	3-62	6
11	1	Ground Systems Design	10-61	9-63	21
12	1	Safety Systems Design	10-61	12-63	27
10	1	Airborne Systems Design	1-62	6-63	18
43	1	Hydrostatic Test Facility	1-62	5-63	16
49	1	Captive Test Stand E-1	1-62	4-64	27
50	1	Captive Test Stand E-2	3-62	6-64	27
14	1	Fabrication Tooling	3-62	6-63	16
7	1	Mockup	--	4-62	--
46	1	Structural Test Facility	5-62	9-63	16
22	1	Component Evaluation Test	6-62	6-65	37
39	1	Training Preparatory Services	7-62	--	--
37	1	Supply Support Concept Established	--	10-62	--
37	1	Spares Provisioning	2-63	--	--
16-20	1	Vehicle Fabrication, Short Stage	2-63	1-66	36
39	1	Training	4-63	--	--
38	1	Maintenance Support Philosophy Established	--	4-63	--
25,45	1	Propellant Flow, Cold (R&D) - Short Stage	8-63	1-65	18
23,46	1	Static Structural Test, Short Stage	9-63	--	$\propto$ 8
24,46	1	Dynamic Structural Test, Short Stage	10-63	--	$\propto$ 7
38	1	Maintenance Support Capability Established	--	12-63	--
28,47	1	Electromechanical Systems Test	2-64	--	16
27,49,50	1	Propellant Flow, Hot (R&D)	5-64	11-64	7
16-20	1	Vehicle Fabrication, Long Stage	9-64	7-66	22
29,49,50	1	Captive Test, Short Stage	11-64	9-65	11
25,45	1	Propellant Flow, Cold (R&D) - Long Stage	3-65	6-66	16
23,46	1	Static Structural Test, Long Stage	4-65	--	$\propto$ 8
24,46	1	Dynamic Structural Test, Long Stage	5-65	--	$\propto$ 7
52	1	Flight Stand Modification, Stand 34	--	8-65	--
54	1	Range and Fallout Net	--	8-65	--
33,34,52	1	Flight Test, Short Stage	9-65	10-66	14
29,49,50	1	Captive Test, Long Stage	12-65	11-66	12
53	1	Flight Stand Modification, Stand 37	--	9-66	--
35,53	1	Flight Test, Long Stage	10-66	5-67	8
35	1	Long Stage Operational	--	6-67	--
5-10	2	Engine Development	7-61	6-64	$\propto$ 36
14-18	2	Engine Development Facilities (Nevada Test Site)	7-61	6-63	24
21,23,25	2	Core Development	--	12-62	--
36-38	2	Engine and Core Delivery	4-63	11-66	44
29	2	Saturn Booster Support - C1 (Single Stage)	--	7-65	--
11	2	PFRT - 55K	--	11-65	--
11	2	PFRT - 80K	--	12-66	--
39	2	Saturn Booster Support - C2 (Two Stage)	--	1-67	--

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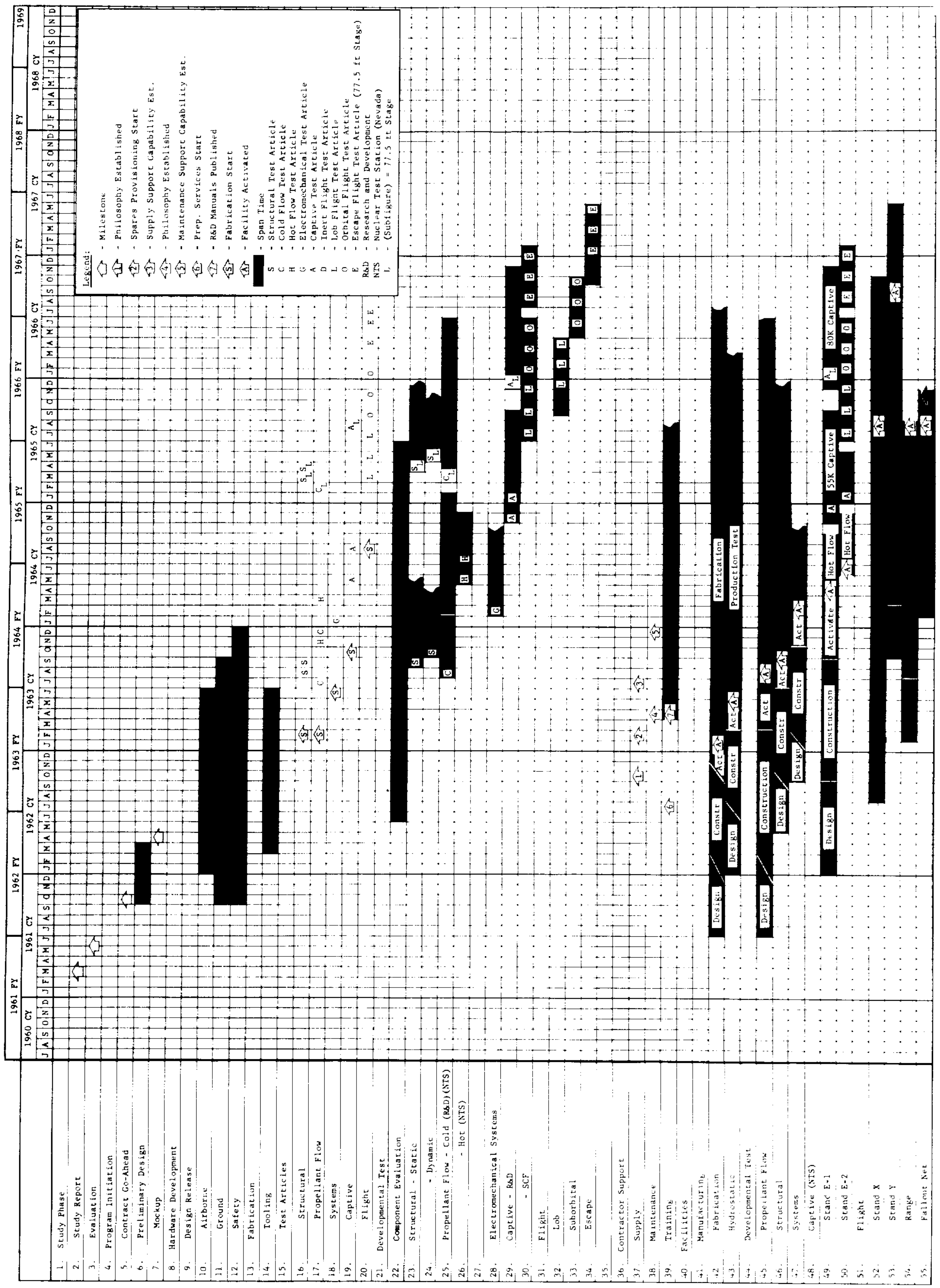

Fig. VII-1 RIFT Program Schedule

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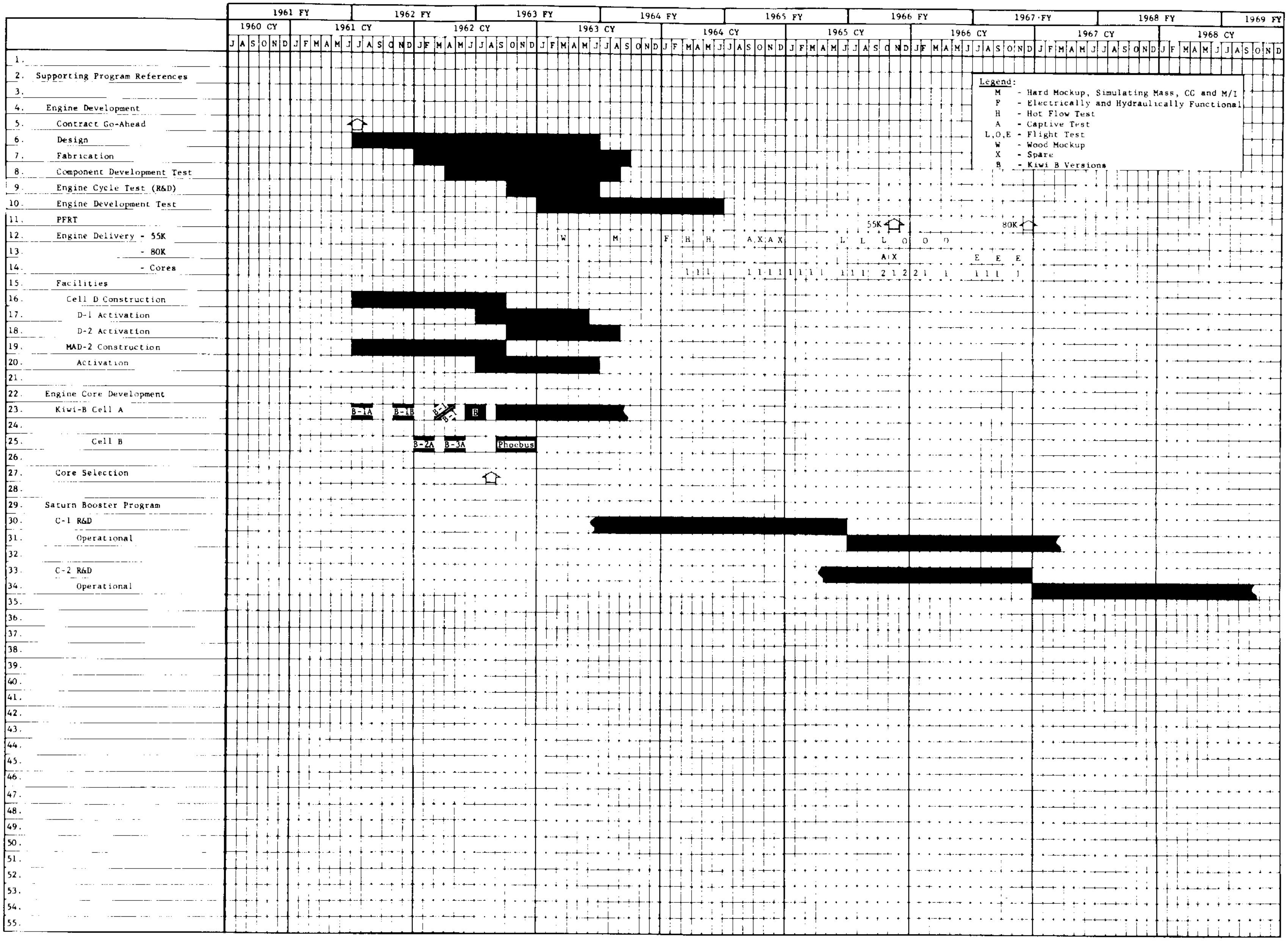


Fig. VII-1 (cont)

The program go-ahead for vehicle design was determined by estimating overall time spans for developmental test, fabrication, and design, allowing a reasonable overlap between these phases, and backing up from the earliest target date. Some of the factors considered in developing the detailed program are discussed in the following paragraphs.

A preliminary design effort to establish general design configuration and requirements would be required to provide a mockup of the vehicle and a start on structural and ground systems design.

Airborne vehicle design would start approximately halfway through the preliminary design phase with a release sequence of structures, systems, instrumentation, and installations.

Benefiting from the structural design criteria established during the preliminary design effort, the release of master lines could be accomplished starting approximately 2 months after the airborne design release effort began. Thus, tool design can begin at this point. Since the short and long stages are both of the same diameter and type of construction, the original tool design will incorporate capability to produce both tank lengths from the same basic tooling.

The test articles and numbers desired, test facilities, and tooling requirements and the general sequence of developmental testing will have been established by developmental test requirements, test objectives, and reliability tests. Component evaluation testing will start soon after airborne design begins, to select or prove the design of airborne and ground systems components which will be incorporated in the overall system. Inputs from these tests will be used in the design effort. The balance of developmental testing will be based on confirmation of system design. Confidence in design capability makes it possible to program a large amount of testing concurrently since the resulting design changes should not involve basic changes to structural or electromechanical systems. Cold flow testing and electromechanical systems testing usually are conducted concurrently and precede captive testing. Captive testing consists of completely ground-testing the vehicle and propulsion system with firings conducted on Nevada test stands. This program qualifies the vehicle for a flight test, but it continues through most of the flight-test program to include solving problems encountered in flight testing. The length of the flight-test program was based on an estimate of the number and frequency of flights required to establish an operational system.

To carry out a development effort involving testing at three widely separated locations requires good planning, integration, and management of logistic support. A substantial training program for test personnel is required. The preparation for this training can begin after ground and airborne design and test planning are firm and producing data upon which to base the training. The training shown on the program schedule is to support the captive and flight test programs. Although some training will be required for Denver test area personnel preceding the depicted training span, it will be informal, on-the-job training. Supply and maintenance support was also programed to include offsite requirements, starting when sufficient design information is available and culminating with support capability immediately preceding the beginning of offsite test activity.

Facility requirements were established by examining developmental, production, captive, and flight test requirements. As a basis for additional facilities needed, the existing Denver, Nevada, and AMR complex facilities presently programed to be available in 1963 and after were compared with the RIFT program requirements. The discrepancy represents test facilities, which are not now in construction or planned to be available in the time period required, or are peculiar to the RIFT vehicle configuration. The cold flow lab and the hydrostatic, structural, and captive test facilities are in this category. Flight test facilities were assumed to be Saturn stands, complexes 34 and 37, which would require some modification for the RIFT program. Facility development time spans were based upon Martin facility experience, and a study on Nevada test site requirements by the architectural and engineering study contractor.

The engine development data were based on preliminary information from a potential engine manufacturer, and on the reactor core development now being conducted. To firm this schedule, completion dates for the engine contractor's preliminary flight rating testing (PFRT) and for engine deliveries were established.

C. EXTENDED RIFT PROGRAM

An alternate plan (Fig. VII-2) is included to show a method of achieving RIFT program objectives with a lower yearly cost and with only a small delay in reaching operational readiness.

Development plan - Development of the operational prototype vehicle only, without intermediate steps, is the essence of this alternate approach. The philosophy, objectives, and approach are essentially the same as those presented in the foregoing discussion. Some of the differences in programing are discussed below.

Concentrating on the operational prototype anchors the flight test effort to the Saturn S-I and S-II booster vehicle. According to information available at this time, this booster should be operational in early 1967. The first two flight tests should be accomplished during the late R&D period for Saturn S-I and S-II configurations. Thus, the flight test program can be completed using reliable boosters and without unnecessary delay in operational capability relative to the program included in the foregoing report.

One vehicle size only, the larger of the two presented in the report, is necessary to carry out the development program. This permits economies in the following areas:

1) Design - both airborne and ground systems;

2) Fabrication - tooling somewhat simplified and fewer test articles required;

3) Ground testing - cold flow, static, and dynamic structural and captive testing required for the shorter stage is not necessary;

4) Facilities - only one flight stand required; captive stand modification eliminated.

Captive stand requirements are delayed approximately 8 months and flight stand and range requirements are delayed approximately 12 months. These changes should effect a significant reduction in yearly facility funding needs.

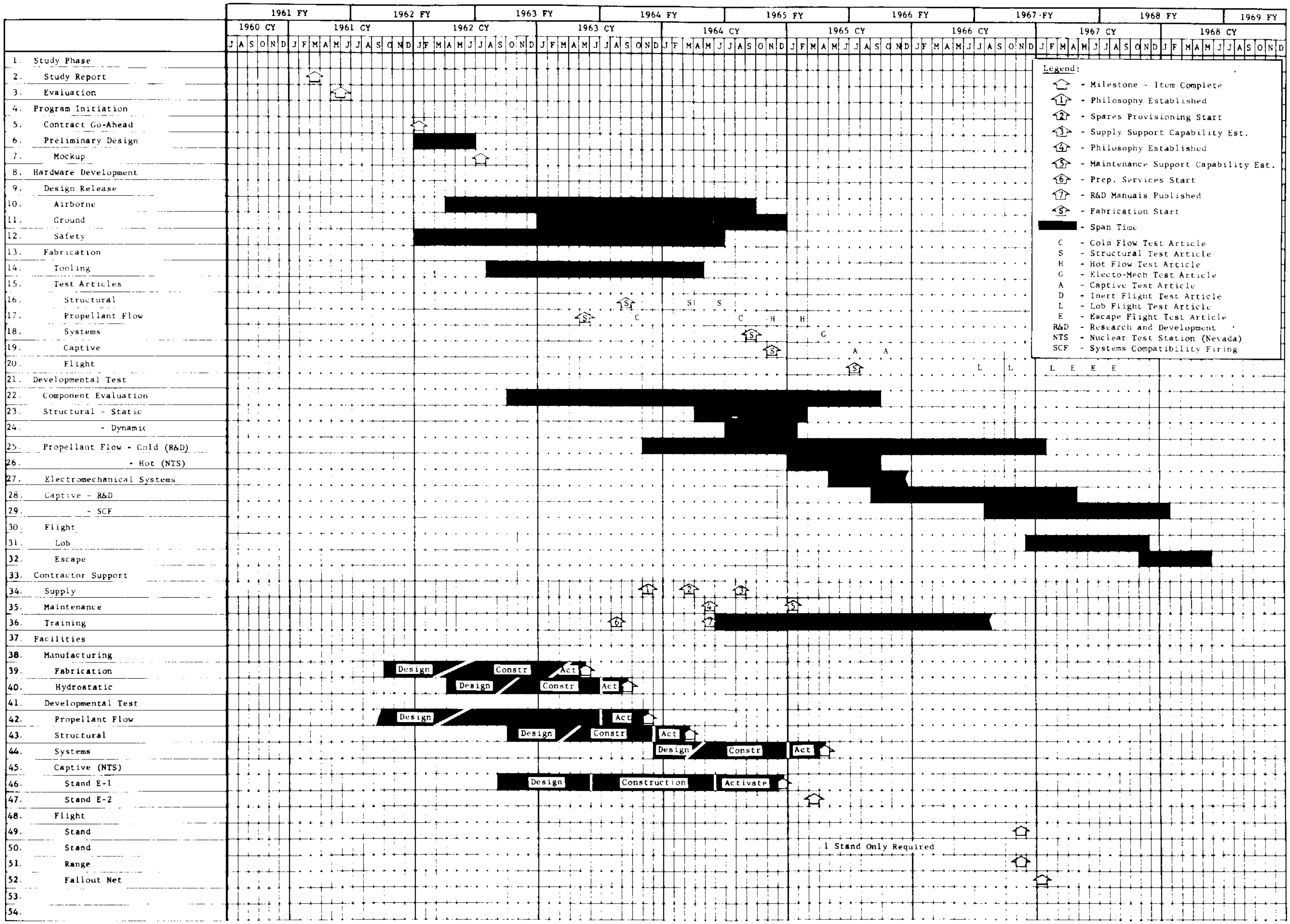


Fig. VII-2 Extended RIFT Program

Program go-ahead on the airframe is delayed only 3 months. This is inconsistent with the fact that the initial flight is about 12 months later, but the reason is to allow more time for design and development testing. This, then, permits broader integration of test results into original design maintenance, and less concurrent testing, with the effect that skilled engineering and technical personnel requirements are not as high as those required to support the first program presented in this primary report.

Contractor logistic support requirements are reduced and initiation of these activities is postponed commensurate with the reduction in developmental test activity. Also, the number of test articles and the training requirements are reduced.

VIII. COST

A. SCOPE OF WORK

The scope of work to be undertaken by the contractor in conjunction with the program schedule and cost outline, which are included herein, shall cover the items described below.

1. Preliminary Design

The contractor shall undertake a six-month preliminary design study leading to the manufacture and fabrication of a complete nuclear-stage vehicle and its associated ground facilities and equipment. Included in this effort will be the fabrication of one mockup of such a vehicle. Completion of this effort will be identified by a preliminary design release that will culminate in the start of the hardware portion of the overall R&D program.

2. Fabrication

Based on the design generated under A above, the contractor shall undertake a program to fabricate the necessary airborne and ground equipment, tooling, test equipment and related items.

Airborne - Over a period of 16 months, the contractor will fabricate 22 nuclear vehicles, consisting of 13 ground test articles and nine flight articles.

Ground - The contractor shall fabricate the necessary GSE, GOE, GIE to support the nuclear vehicle and the related test programs.

Tooling and test equipment - The contractor shall fabricate and/or procure the necessary tools and test equipment associated with the overall program. The tooling will be sufficient to support the production of 22 vehicles.

3. Developmental Tests

The contractor shall undertake the test program to assure component and end-item performance. The test programs shall include component evaluation, dynamic and static structural tests, cold propellant-flow tests, electromechanical system tests, and captive and flight tests.

Nevada - All tanks and engines will be assembled at the Nevada test site, where the contractor shall conduct preflight tests preliminary to full-flight at AMR.

AMR - The contractor shall conduct a series of nine full-flight tests, including three lob, three orbital, and three escape.

4. Contractor Support

The contractor shall provide necessary support and services consisting of supply, maintenance and training for the overall program, including airborne and ground equipment and their associated requirements.

Supply - A parts depot and the required personnel will be maintained at the contractor's facility and will furnish the necessary operating inventory and related services.

Maintenance - The contractor shall provide a complete maintenance program to assure proper reliability and performance of ground equipment and test equipment.

Training - The contractor shall undertake a program of training of the necessary instructors, personnel, and field crews required at various locations sufficient to support the overall program objectives.

5. Facilities

In anticipation of this program, the contractor plans to make an orderly integration of facility additions into the existing facilities. Facility plans make maximum use of existing instrumentation, test equipment, and utilities.

[redacted]

B. COST ANALYSIS

A costing analysis was conducted for the program plan and scope of work as presented by this contractor. It should be noted that the contractor has assumed the role of program manager for the complete development and test program. The program extends beyond RIFT demonstration flights into operational usage on the Saturn S-I/Nuclear and S-II/Nuclear configurations. For this reason, logistic support, including crew training and spares, has been included at a level that will support a continuing operational program. The program costs presented represent the total cost to government including the portion which may be allocated to a RIFT stage contractor.

The contractor's location was assumed as the Denver Division of The Martin Company. Table VIII-1 presents costs of the RIFT program broken down by the geographical locations of Denver, USAEC Test Center, and AMR.

The total cost of this program is 520.8 million dollars. The fiscal year expenditures are given in Table VIII-2, which is based on a go-ahead date of 1 July 1961. The personnel total required at all locations for design development support and test operations is given in Figure VIII-1.

The following ground rules applied to the data given in Table VIII-1:

1) The research and development costs for the nuclear engine were not included;

2) Nuclear engine costs including reactor were 4 million dollars each;

3) The Saturn booster costs are included without consideration of any R&D costs, at 4.1 million dollars each for the S-I and 6 million dollars each for the S-II stages;

4) Contractor fees are not included.

All figures given are in summary form; however, greater detail will be provided if desired.

These costs are for the program schedule shown on Figure VII-1.

[redacted]

[redacted]

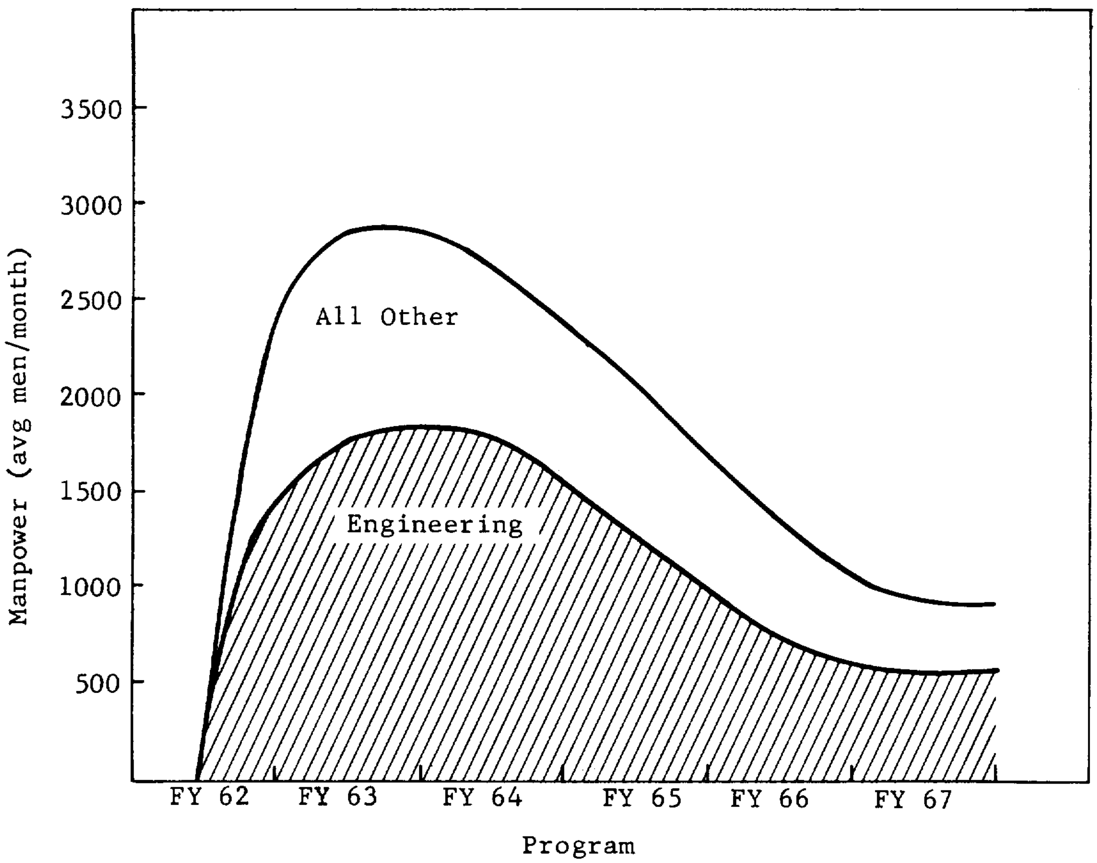
Table VIII-1. Program Summary by Location

	Program Total (thousands)	FY 62	FY 63	FY 64	FY 65	FY 66	FY 67
Contractor Location	$273,497	$24,495	$71,515	$ 70,294	$ 61,205	$27,010	$18,978
USAEC Test Center	138,689	12,183	6,855	33,854	45,143	25,833	14,821
AMR	108,651	--	1,443	3,571	7,637	34,865	61,135
Program Total	$520,837	$36,678	$79,813	$107,719	$113,985	$87,708	$94,934

[redacted]

Table VIII-2. Program Cost Study

	Program Cost (in thousands)	Funding Requirement					
		FY 62	FY 63	FY 64	FY 65	FY 66	FY 67
Contractor Location							
Facilities	$ 13,469	$ 5,707	$ 4,638	$ 2,050	$ 720	$ 231	$ 123
Engineering and Direct Charges	186,243	16,965	45,592	47,907	34,436	22,638	18,705
Fabrication (including tooling)	33,394	1,005	9,757	8,897	9,484	4,141	150
Test Equipment	5,802	817	4,476	233	236	--	--
GSE/GIE/GOE	3,160	--	1,579	786	795	--	--
GFE Support	339	--	113	113	113	--	--
Data and Reports	830	--	140	225	465	--	--
Depot Establishment and Operation	29,200	--	4,866	9,732	14,602	--	--
Training Personnel Support	1,060	--	353	353	354	--	--
Subtotal	273,497	24,495	71,515	70,294	61,205	27,010	18,978
USAEC Test Center							
Facilities	19,661	12,183	5,228	1,575	374	188	113
GFE Maintenance	1,133	--	--	113	567	283	170
GSE/GIE/GOE	10,151	--	--	1,015	5,075	2,538	1,523
Engines and Reactors	76,000	--	--	27,500	30,500	13,500	4,500
System Test	9,029	--	727	1,984	3,051	2,262	1,005
Activation	3,000	--	--	300	1,500	750	450
Depot Establishment and Operation	292	--	--	--	98	97	97
Base Operation and Spares	12,270	--	--	--	1,525	4,823	5,922
Training	4,673	--	--	467	2,337	1,168	701
GSE for Nuclear Engine	1,800	--	900	900	--	--	--
Data and Reports	680	--	--	--	116	224	340
Subtotal	138,689	12,183	6,855	33,854	45,143	25,833	14,821
AMR							
Facilities	1,719	--	201	1,249	269	--	--
GSE/GIE/GOE	9,228	--	--	--	2,225	4,235	2,768
Gantry and Umbilical Modification	1,800	--	180	1,260	360	--	--
GSE for Nuclear Engines	1,800	--	900	900	--	--	--
Systems Test	3,614	--	162	162	849	1,429	1,012
Activation and Base Establishment	10,240	--	--	--	2,048	4,345	3,847
Depot Operation and Spares	1,261	--	--	--	420	420	421
Training	3,374	--	--	--	675	1,687	1,012
Boosters and Propellant	51,923	--	--	--	480	12,354	39,089
Reactors	22,500	--	--	--	--	10,000	12,500
GFE Maintenance	662	--	--	--	221	221	220
Data Reports	530	--	--	--	90	174	266
Subtotal	108,651	--	1,443	3,571	7,637	34,865	61,135
Grand Total	$520,837	$36,678	$79,813	$107,719	$113,985	$87,708	$94,934



Average Engineer Manmonths	1375	1750	1750	1200	750	600
Average Other Manmonths	352	1099	904	892	588	328
Average Total Manmonths	1727	2849	2654	2092	1338	928

Fig. VIII-1 Manpower Chart

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